Vol. VI. — No. 10. October 1924.

UNIVERSITY OF ILLINOIS URBANA

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION

625 .143.3 & 625 .143.4]

REPORT No. 1

(America)

ON THE QUESTION OF BREAKING OF RAILS; JOINTS (SUBJECT II FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), [1]

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ENGINEER OF STANDARDS, PENNSYLVANIA RAILROAD SYSTEM.

Figs. 1 to 32, pp. 681 to 772.

A. — Breaking of rails.

Classification of rail failures.

Even with the elaboration of the caption, the reporter is confronted with the necessity for his own interpretation of the meaning of « broken rails », which may be quite different from that of Europe and Great Britain. In the United States and Canada, the general and comprehensive term for a rail which is considered unfit for further use in the track by reason of a suspicious defect, though it may not be broken, is « rail failure ». The « broken rail » is but a sub-division of « rail failure », though the most important sub-division.

When a rail shows the slightest suspicious defect, it must be removed from the track as quickly as possible, and be reported as a rail failure ». It may be a dark colored black streak on the service surface of the head longitudinally with the centre line, a rust streak having the appearence of a minute crack underneath the head at the junction with the web, a longitudinal crack in the rail web, or something which has the appearance of a crack or fold in the base. All these are « rail failures », but not « rail breakages ». They are removed because they *may* become « rail breakages » with continued service, although it is possible that the defect might develop so slowly that it would not break down for a considerable period. Even then it may not become a « broken rail », but would be classified as, « flow of metal », « crushed head », « split head », « split web », or « broken base », and so reported.

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[1] This question runs as follows : « *A*) Initial causes of breaking of rails : means employed to reduce the number of these breakages, as much from the point of view of the method of use as from that of the specification of material employed. — *B*) Rail joints : most economical and efficient arrangement. »

Reporting rail failures.

In order that these classifications be understood, a copy of the « rail failure report », with the rail failure classifications on the reverse side, is illustrated as Exhibits 1 and 2. They are based on the track foreman's common appelation applied to the different kinds of failures, except in the case of « transverse fissure », and are not such as might be given by an engineer physicist or a chemical or metallurgical engineer who whould base his classification upon the « cause » as discovered in the laboratory. This is impraticable, as the name must be given when the defect is discovered in the track, and a very small proportion of the defective rails ever reaches the laboratory.

The question of orderly and systematic method of reporting and studying rail failures confronted the Rail Committee of the American Railway Engineering Association early, and the plan as finally adopted is given in considerable detail in *Proceedings, American Railway Engineering Association*, vol. X, part I, 1909, p. 339.

It is thought by the railway engineers of the United States that there has been misunderstanding on the part of the railway engineers and rail manufacturers in Great Britain and Europe in regard to this designation, « rail failures », and that they have been considered as « rail breakages » in making comparison with the breakages in those countries.

There is another cause for discrepancy in making comparisons, which exists between the railroads of North America, as between *some* of the railroads of North America and those of foreign countries, and it is that certain portions of main tracks of light traffic laid with « fit » or « repair » rail or even new rail of light weight are excluded from the rules for reporting rail failures.

The Rail Committee of the American Railway Engineering Association considers, in order to make comparisons of failures accurate and fair, that rail failure reports should be sent forward for all main tracks, no matter what the difference in traffic might be, and for all kinds of rail, no matter what the weight or the section or profile might be, or whether or not it were laid with new or old rail. This result has not been accomplished entirely as yet.

This explanatory statement is necessary, for the railroads which have sent in answers to the « questionnaire » of the reporter have assumed that « breaking of rails » include all kinds of rail failures, and the reporter will deal with the subject, therefore, from that point of view.

There are sufficient differences and omissions in the answers received to make it impossible for the reporter to make a tabulation of them, and he will be obliged to present the study somewhat differently from the arrangement of the questionnaire.

Rail failure analysis.

Rail failures can only be studied quantitatively, grouped in different clas-

EXHIBIT 1.

nstructions and
Description of
'ailures on Back.

.... Region Report No. ....
.... Division .... Branch

REPORT OF RAIL FAILURE IN MAIN TRACK.

Nearest to .... *Station, State of* ....
Section No .... *Date of Report* .... 192....

1. Pounds per yard ...... 2. Rail Section ....
3. Rail Mill ....
4. Date Rolled F. ....
5. Kind of Steel G. ....
6. Heat number H. .... 7. Ingot No. K. ....
8. Rail Letter H. .... 9. Rail Length ....
0. Was Rail — New?... Rerolled?... Resawed?. .
1. Month and Year Rail was Laid ....
2. Location E. . . . feet North or West of Mile Post ...
3. Which Track? ...... 14. Which Rail? ....
5. High or Low Rail of Curve .... or Tangent. ...
6. Degree of Curve I. .... 17. No. of Curve I. ....
8. Superelevation of High Rail at Failure ....

19. Was Rail much or little worn? ....
20. Date and Time Found ....
21. Was Rail removed? ...... 22. Date removed....
23. Exact Gauge of Track at Failure ....
24. Kind of Ties ....
25. Were Tie Plates used? .... 26. Kind ......
27. Condition of Line and Surface ....
28. Kind of Ballast ....
29. Was Track properly ballasted? ....
30. Kind of Material in Roadbed under Ballast ....
31. Was Track well drained? ....
32. Was Roadbed frozen? ....
33. Rail removed will be at ....

4. Describe Failure, together with Flaws or Defects, and state Cause as nearly as may be : ....
....
....

If Failure was « Broken Rail ».

5. Was Break square or angular? ....
6. Was Break over or between Ties? ....
7. Condition of Ties each side of Break? ....
8. Was cause
   - Transverse Fissure? ....
   - Horizontal Fissure? ....
   - Detail Fracture? ....
   - Sudden Rupture? ....
9. Was Rail in track circuit? ....
0. Was signal set to « STOP » by Break? ....

41. Indicate « Gauge Side » by crossing out repeated words on opposite side of Figs. 1. & 2. ....

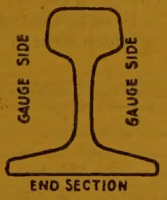


Fig. 1.

42. Was Break outside of Joint?J If Break was « in Joint », stateJ .
43. Name of Joint ....
44. Designating No. of Joint........
45. If insulated or not ....
46. No. of bolt holes ....
47. No. of bolts loose ....
48. No. of bolts missing ....

9. Sketch position and shape of Transverse Fissure on « End Section » and state size : I-A. ....
0. State how many additional Fissures were found in this Rail, if any, ... and at what distance from first one, and how located with reference to gauge side of head ....
....
1. How many rails, if any, adjacent to this one were removed because of Fissure ....
2. Draw on diagram **defects** and **lines of break**, or partial fracture, such as long pieces from side of head, and half moon pieces from base, showing dimensions and following distances :
   - (*a*) Distance from nearest end of Rail to break or defect.
   - (*b*) Distance between edges of Ties near break.
   - (*c*) Distance from end of Rail to near edge of first Tie « Y ».
   - (*d*) On double or more main tracks.
     - If break is nearest « Receiving End » cross out words « Leaving End ».
     - If nearest « Leaving End » cross out words « Receiving End ».

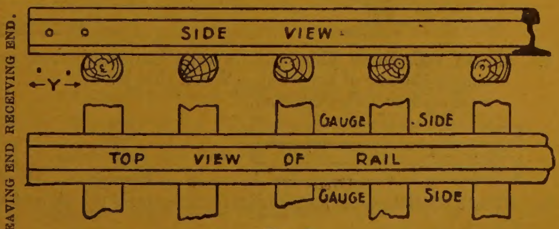


Fig. 2.

3. If accident or detention to trains was caused by Break, state circumstances. ....
....
4. Was any passenger, employee or other person injured because of Rail Failure? ....
5. Show by « X » in square if Weather was Wet ☐ or Dry ☐ Warm ☐ or Cold ☐ Freezing ☐ or Thawing ☐.
6. If « Damaged », describe nature and cause if known (report No. of train, engine or car) ....
....

orrect : *Approved :*
.... *Foreman* .... *Supervisor.*

Front.

EXHIBIT 2.

INSTRUCTIONS.

A. One of these blanks shall be filled in for each Rail which fails in a Main Track and is removed on account of being broken, defective or damaged as shown in the « Description of Rail Failures » below. Do not fill in blank for Rails which are worn out in stretches and are ready for replacement by new Rail, even though the failure may be due to flattening of the head, or other results of poor material.

B. The Foreman will send this report to the Supervisor the same day the break is found and in the case of a damaged or defective rail, the day it is taken out of the track.

C. The Supervisor will forward this report direct to the Division Engineer, who will send a copy to the Chief Engineer M. of W.

D. The term « Main Tracks » has the same meaning as in the « Book of Rules » and includes « Single Track », « Double Track » and « Three or more Tracks ».

E. Mile Post number from Southeast end of Division to be used. (Question 12.)

F. The « Date Rolled » (Question 4), is shown by raised figures and lines, on the web of the Rail, the month being indicated by the number of parallel vertical lines.

G. The « Kind of Steel » (Question 5), is Bessemer «(B)» ; Open Hearth «(O H)» ; Nickel «(N)» ; Ferro-titanium «(FT.)» Chrome Nickel «(CN.)» or other alloy or way of making.

H. The « Heat Number » (Question 6), and the « Rail Letter » (Question 8), are stamped into the metal on the side o the web opposite to the side on which the « Brand » is rolled, figures for « 6 » and a letter for « 8 ».

I. « Degree of Curve » (Question 16), and « No. of Curve » (Question 17), are given on plans or information stakes.

J. « In Joint » applies to Rail where failure starts within length covered by the joint bars.

K. The « Ingot Number » is stamped on the side of the web by some makers (not yet universal).

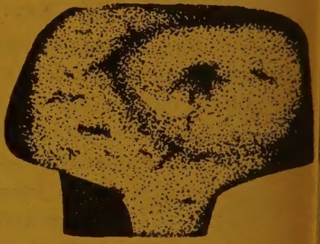
DESCRIPTION OF RAIL FAILURES.

When describing Failures of Rails, the following terms should be used :

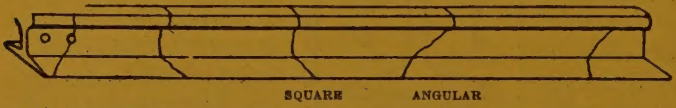
1. BROKEN RAIL :

(A) **Transverse Fissure.** — A crosswise break starting from a center inside the head of the rail from which the defect spreads outward. The broken rail will show a smooth bright or dark oval spot in the head.

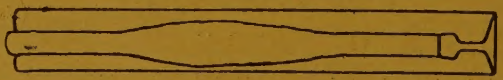
(B) **Ordinary Break.** — This term covers all partial or complete fractures (square or angular breaks) in Rails in which there is no Transverse or Horizontal Fissure, and in which none of the defects or damage described below are visible.

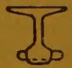


INTERNAL TRANSVERSE FISSURE.

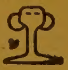


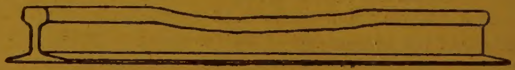
2. FLOWED HEAD. — This term means a « Rolling out » of the metal on top of the head toward the sides withou showing any indication of a breaking down of the head structure ; that is, the under side of the head is not distorte or split.



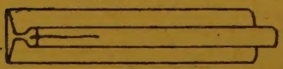


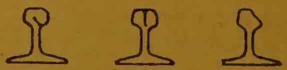
3. CRUSHED HEAD. — A « Flattening » of the head usually accompanied by a crushing down of the metal withou any indication of a crack on the underside of the head.

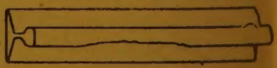




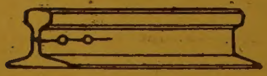
4. SPLIT HEAD. — This term includes Rails split along or near the middle of the head of Rails with pieces split off t side or the end of the head. When this term is used, it should be reported whether it is, or is not, accompanied a seamed or hollowed head.

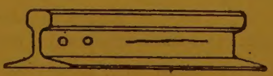


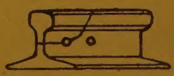


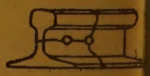


5. SPLIT WEB. — A longitudinal crack along the side of the web.

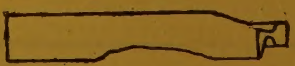


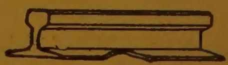






6. BROKEN BASE. — Any break in the base of a Rail. It should be described and sketched on the diagrams on front page.





7. DAMAGED. — Under this head will be included all Rails broken or injured by wrecks, broken wheels slipping similar causes.

Back.

sification if desired, or by a chemical, metallurgical, and microscopical survey of single rails, which includes the melt of metal from which they were rolled, and the mill operations of manufacture.

Rail failures are too numerous for the plan of putting them all through the laboratory survey, and accordingly quantitative statistics have been used for comparing the product of the several mills with one another, and the difference in service obtained by the different railroads.

Quantitative statistics, in order to be of any use, must be placed upon a « unit basis », and this unit should be a true measure of the service performed. This unit is, of course, the ton-mile of traffic, but it is not complete in itself as there is another element of variability, the character of the alinement of the track. This is more important in the study of rail « wear » or durability, but it has an important influence on rail failures as well, for the rail is more severely punished on the line with very sharp (short radius) curves than on the one with a greater proportion of tangent track and long radius curves.

However, with the great variations in traffic on the different portions of a railroad system, it is impracticable to obtain a correct division of the traffic on these different portions and over the several tracks of a three-, four-, or multiple-track railroad, and the establishment of a unit of comparison for topographical location and other physical characteristics as between railroads is impossible. Therefore, as the next best subsitute plan, the American Railway Engineering Association has adopted the unit of 100 miles of track laid with the rail to be studied for the purpose of making comparisons.

Record of failures.

The latest compilation of quantitative figures of that Association is given in the table 1 and diagram (fig. 1). The measure of performance of each year's rolling is taken as the failure per 100 miles of track for five year's service, the failure rate for each year being based upon the amount of the rail left in the track at the time of the report. It embraces the record for about 1 000 000 tons of rail laid annually.

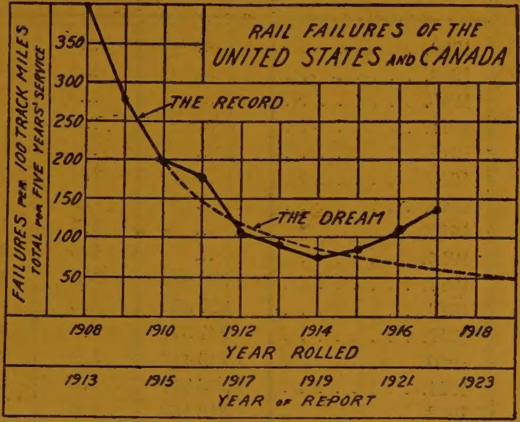


Fig. 1.

The diagram shows the improvement in the reduction in rail failures (not breakages) since 1908, and « the dream » is the curve of hoped-for future accomplishment drawn in 1915, and shattered by the war period of neglected maintenance and hasty manufacture.

However the four-year record for the 1918 rolling shows a decrease which may indicate future reductions, and the resumption of « the dream ».

Table 1.

UNITED STATES AND CANADA.

Accumulated failures for rollings from 1917 to 1921.

(Per 100 track-miles.)

Year rolled.	Tons rolled.	Years service.					
		0	1	2	3	4	5
1908.	...	...	...	...	...	...	398.1
1909.	...	...	...	...	...	224.1	277.8
1910.	...	...	...	...	124.0	152.7	198.5
1911.	...	...	...	77.0	104.4	133.3	176.3
1912.	...	...	28.9	32.1	49.3	78.9	107.1
1913.	...	2.0	12.5	25.8	44.8	69.5	91.9
1914.	...	1.2	9.2	19.8	32.9	50.9	74.0
1915.	...	0.7	8.9	19.0	34.2	53.0	82.4
1916.	...	1.6	11.8	29.2	47.7	70.6	105.4
1917.	1 050 632	5.3	21.6	38.9	66.0	110.5	137.0
1918.	917 050	1.6	8.9	27.6	54.0	92.8	...
1919.	947 577	2.0	14.8	39.4	73.7	...	...
1920.	1 146 419	3.9	14.2	32.4	...	..	..
1921.	1 138 048	1.6	10.9	...	...	...	...
1922.	818 128	1.5	...	...	...	...	...

Ratio of types of failures.

For railroads of heavy traffic, the predominant ratio of each classified type of failure to the total is approximately as follows :

Table 2.

Classified type of rail failure.	Ratio to total failures.	The ratio may vary from.
Broken rails :	Per centum.	Per centum.
A. Internal transverse fissure.	20	15 to 28
B. Ordinary break . .	31	30 to 35
Flow of metal.	3	1 to 9
Crushed head	7	5 to 20
Split head	17	15 to 20
Split web	21	10 to 25
Broken base.	1	1 to 17

When the roads of light traffic are considered, it is found that none of the broken rails is of the transverse fissure type, and indeed that rail breakages are so few that there is no problem of rail safety. The strength of rail and metal are so far beyond the requirements of traffic service that there is no menace from rail rupture. That is the principal reason for fewer rail failures in one country than another, or on one railroad compared with another. The ratio of strength of rail and metal to the service rendered is greater in one case than the other.

There is an important exception, however, to be borne in mind and dealt with later on in this study, and that is the fact that *all the product* of *all* the mills is not of equal quality. There are differences in mill practice which result in

Table 3.

Date of rolling.	Weight of rail, in lb. per yard.	Tons rolled.	Total rail failures of all kinds.			
			« X » railroad.		« Y » railroad.	
			1st 5 years.	2nd 5 years.	1st 5 years.	2nd 5 years.
1908	80	4 963	3	32	...	...
1909	80	15 005	3	40	...	...
1910	...	...	...	...	...	...
1911	80	4 098	10	2	...	...
1911	85	5 985	25	112	...	...
1911	100	4 026	...	...	98	153
1911	110	4 967	...	...	64	169
1912	80	3 183	0	3	...	...
1912	85	7 063	46	111	...	...
1912	100	23 298	...	...	544	582
1912	110	2 140	...	...	40	13
1913	80	2 438	0	...	...	...
1913	85	6 680	2	...	...	...
1913	90	8 063	38	...	...	...
1913	100	50 538	...	...	607	776
1913	110	14 104	...	...	173	162
1914	80	2 512	6	...	...	...
1914	90	3 931	14	...	...	...
1914	100	30 343	...	...	60	...
1914	110	5 950	...	...	13	...
1915	80	3 000	15	...	...	...
1915	90	2 889	22	...	...	...
1915	100	4 738	...	...	2	...
1916	90	6 190	40	...	...	...
1916	100	9 461	...	...	21	...
1916	136	2 538	...	...	50	...
1917	90	2 831	75	...	...	...
1917	100	2 783	...	...	11	...
1917	136	12 253	...	...	271	...
1918	100	3 772	...	...	14	...
1918	136	7 141	...	...	9	...

better finished material, and this leads us to the division line of the questionnaire, « Breakages attributable to the use to which the rails are put », and « Breakages attributable to defects in the metal in the rails ».

3. Breakages attributable to the use to which rails are put.

Effect of age.

Having assumed that the rail metal was homogeneous and of a prescribed strength, it was the problem of the earlier engineers to proportion the rail as a girder for the traffic it was intended to carry, and he was obliged in addition to forecast the future for many years, and make adequate allowance for the hoped for increase in business. It is plainly evident that the effect of « age » on the problem was nil, except in so far as rail renewal was postponed beyond its service limit. The accompanying sulphur print illustrates this well, as the rail was used in the main track of a minor division continuously for 34 years, and is not much worn at that (fig. 2).

Breakages in each contract.

Only five of the respondents to the request for number of breakages of rails up to five years old, between five and ten years old, and so on for each five years, have furnished information and their answers include all kinds of failures as well as breakages. Not being expressed on a unit basis, and covering but a small proportion of the mileage, they cannot be used in comparison. The best information has been given by the data of American Railway Engineering Association, outlined above.

Only two of them can be tabulated in table 3.

A third railroad gives its tabulation as follows :

Type of failure.	Broken.	Split head.	Battered and crushed	Cracked in web.	Base break.	Total.
1st 5 years . .	203	593	187	171	307	1 461
2nd 5 years . .	217	1 517	716	180	275	2 905
3rd 5 yers. . .	165	1 141	586	71	74	2 037
Total. . .	585	3 251	1 489	422	656	6 403

This statement of the Illinois Central Railroad is shown because it is given in accordance with the unit basis, and is complete :

Total failures to date per 100 track miles per year of rail in service.

Year rolled.	Broken.	Head.	Fissure.	Web	Base.	*Remarks.*
1918	1.75	23.0	5.41	3.58	0.43	All 90-pound RA-A section of rail.
1919	1.97	23.5	9.02	6.15	0.78	
1920	0.81	19.8	3.40	1.70	0.52	
1921	0.96	6.2	1.20	1.93	0.48	
1922	0.83	23.1	0.42	2.51	0.84	
Total., 5 years. . .	1.38	20.4	4.93	3.63	0.62	...

Effect of wear.

At the Institute of Transport Congress in Sheffield, June, 1923, Sir Robert A. Hadfield (1) « said that rails failed, in the main, either by fracture or excessive wear ».

As a general rule in North America, rails are not allowed to remain in the track until they are so much worn that they are unsafe.

They are needed in other tracks of different and lesser service, and the important tracks carrying heavy traffic at high speed obtain the advantage of new rail. They are thus kept in a higher degree of condition.

The rules for allowable abrasion before removal are not uniform, as the conditions of service are quite different in the many territories of operation. Generally, however, on curves 20 to 28 % of the head area is worn away before replacement, although on curves of 3° or less, replacement will be made probably for other reasons before that amount has been lost. On tangents, the practice is more variable, because in some cases rail is replaced much before worn out on account of being required in good condition for branch service. This may be as little as 1/8 inch for 85 or 90-pound rail, and as much as 3/4 inch for 130-pound, and 5/8 inch for 100-pound. The worn rail classification gauges in use on the Pennsylvania Railrold system are illustrated in figure 3.

Therefore, rail-wear as a factor of rail breakage in rail service need not be of much importance. Rail-wear, however, is studied constantly by the engineers in an effort to obtain metal of greater resistance to abrasion in order to bring about economy in renewals. Having to renew rails in certain locations every nine months under heavy and continuous traffic, as is done in some locations on the Pennsylvania Railraod System, has caused that company to devote much study to the problem and to carry on extensive service trials.

In order to bring about greater resistance to wear, railroads have made trials of alloy steels which require heat-treatment to develop the full value of their effect, and heat-treatment of carbon steel without alloy.

The latest collection of data from service trials of these selected rails, manganese steel, nickel, chromium-nickel, and steels with specially active oxidizers, titanium, aluminium, vanadium, high silicon, etc., is contained in the reporter's report on question III, Special Steels, to the International Railway Congress Association, ninth congress, Rome, 1922 (1).

The progress in heat-treated carbon steel rails was recorded, and data given in connection with special trials of rails finished in the electric furnace, rails made from Hadfield sink-head ingots, and rail-heads cooled by an air blast in accordance with Mr. Sandberg's patent for producing sorbitic microstructure.

Manganese when raised to the amount of 10 to 14 % has won an important place in rail steel on account of the great toughness and resistance to abrasion on sharp curves of the resulting steel, but, on account of its high cost ($155.00 per ton) it is only economical for those curves of short radius where the traffic is heavy and grinds away the carbon steel in a brief period. It is not economical for tangent track or track with long radius curves. It has certain short comings which have not yet been overcome and prevent its general use in rail steel :

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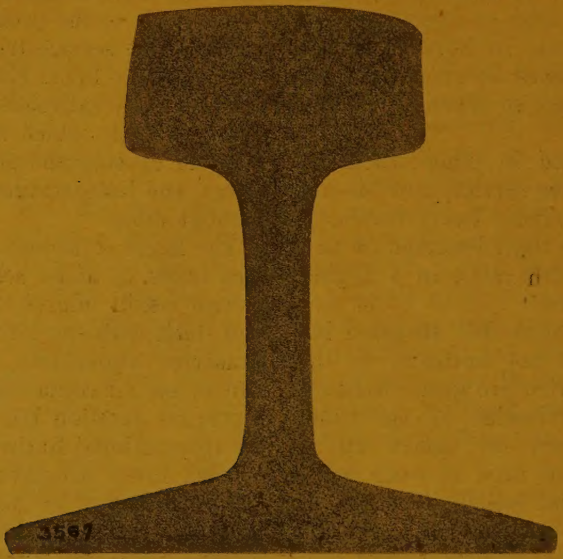
(1) *Engineering*, 22 June, 1922.

(1) See *Bulletin of the International Railway Association*, June 1921, p. 577.

1° The elastic limit is low, 30 000 to 35 000 pounds per square inch, and a number of breakages has been recorded;

2° It is strong and tough, but the hardness is not superior to that of Bessemer steel, and consequently the resistance to batter at the ends of the rails is not altogether satisfactory.



60 lb. P. R. R. Laid : 3-1889. Removed : 11-3-23.

	Bessemer					
Borings.	C.	Mn.	P.	Si.	S.	Average Brinel hardness.
Head « O ». . .	0.470	0.48	0.109	0.052	0.030	195
Web « M ». . .	0.404	0.46	0.095	0.052	0.030	184

Brinell hardness on top of head at centre 218.

Fig. 2.

Although trials of manganese steel rail have been made by a dozen other railroads, those which are making use of the manganese steel rail at the present time are the Delaware, Lackawanna & Western Railroad, Southern Pacific Company, New York Central Lines, and Pennsylvania Railroad System. No manganese rail of heavier section than 100 pounds per yard had been rolled up to the end of the year 1923, but during the current year, the Illinois Steel Company has rolled manganese rail of the 130 pounds P. S. section for the Pennsylvania Railroad System. It can be a part of the rail allotment to good advantage for those railroads with crooked alignment and heavy traffic.

The use of nickel in rail steel in the amounts tried, 3.25 % to 5.00 %, could not be considered as having accomplished its purpose, reduced-wear at less cost.

The use of chromium-nickel together in rail steel in the proportions tried, nickel 2 to 2 1/2 % and chromium 0.50 to 0.90 % gave unsatisfactory results because greater resistance to abrasion was at the expense of greater brittleness. Alloy steels require heat-treatment in order to develop their resisting properties. That is probably the principal reason for success with high manganese steel. It may be truc also that the correct properties of the other alloys in order to make tough and strong material of high elastic limit for rail steel have not been found.

Elasticity of formation.

As long as railroads must be built on a yielding soil, there will be elasticity of the formation, but this is a detriment and not an advantage. The elasticity should be in the vehicle and not in the formation. The springs of the rolling stock should be of the required strength and action. The greater the yielding of the road-bed under a heavy load at high speed the greater will be the destructive action. The smoother and more unyielding the rolling surface, the better will the load be carried. As this condition cannot be brought about on embankments of earth, gravel or rock, the railway engineers overcome as much of the defect as possible with a thick bed of rock ballast, strong ties of substantial dimensions spaced closely together, and heavy rail combining strength and stiffness.

The trials of concrete to replace the ballast have been doomed to failure from the inception because of this yielding soil underneath. It was bound to break up as it did, because restoration of accurate surface and alignment of track for carrying heavy loads at high speed must be brought about when impaired. Any method of constructing track, short of a foundation as in bridge work, will be a failure if no provision has been made for convenient and economic repair. The story of concrete track built on rock or structural steel as in stations and tunnels is quite different.

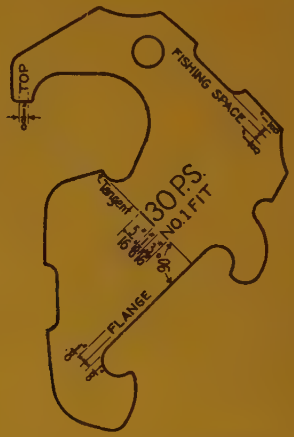
No record of the effect of an elastic or non-elastic formation upon rail breakages has been furnished the reporter, but some have called attention to the well known fact that there are more rail breakages in winter than in summer.

It appears to the reporter that the real reason is the lack of opportunity for suitable maintenance of the track, and not the rigidity of the frozen road-bed. The track is frozen very unevenly, according to the degree of water saturation, and this causes it to be « heaved up » in spots as the trackman expresses it, and he begins that crude method of restoring the surface, shimming. This work is difficult to do well and accurately and the result is quite an uneven surface, bringing about greater shocks and additional punishment of the rail by the moving traffic.

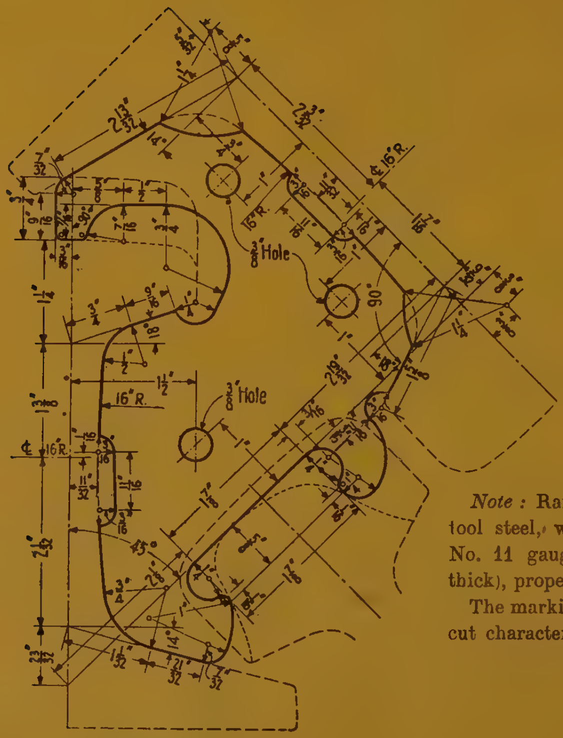
Inclination of rail.

Such systematic and recorded trials of track laid with rail inclined in comparison with track laid with rail axis at right angles to the ties as have been made in this country have not indicated any effect upon increasing or decreasing rail breakages, or, for that matter, rail failures. Very few such trials have been made, and the companies answering the questionnaire furnish no data. Several of them express their opinions, some of which are based upon observations of their own track laid in both ways :

The Lehigh Valley Railroad, Wabash Railway, Chesapeake & Ohio Railway, Illinois Central Railroad and Chicago & North Western Railway believe that breakages are reduced by inclined rail.



Detail of typical marking which shall be placed on both sides of gauge.



Note : Rail gauges shall be made of tool steel, which will not corrode, of No. 11 gauge (approximately 1/8 inch thick), properly tempered to resist wear.

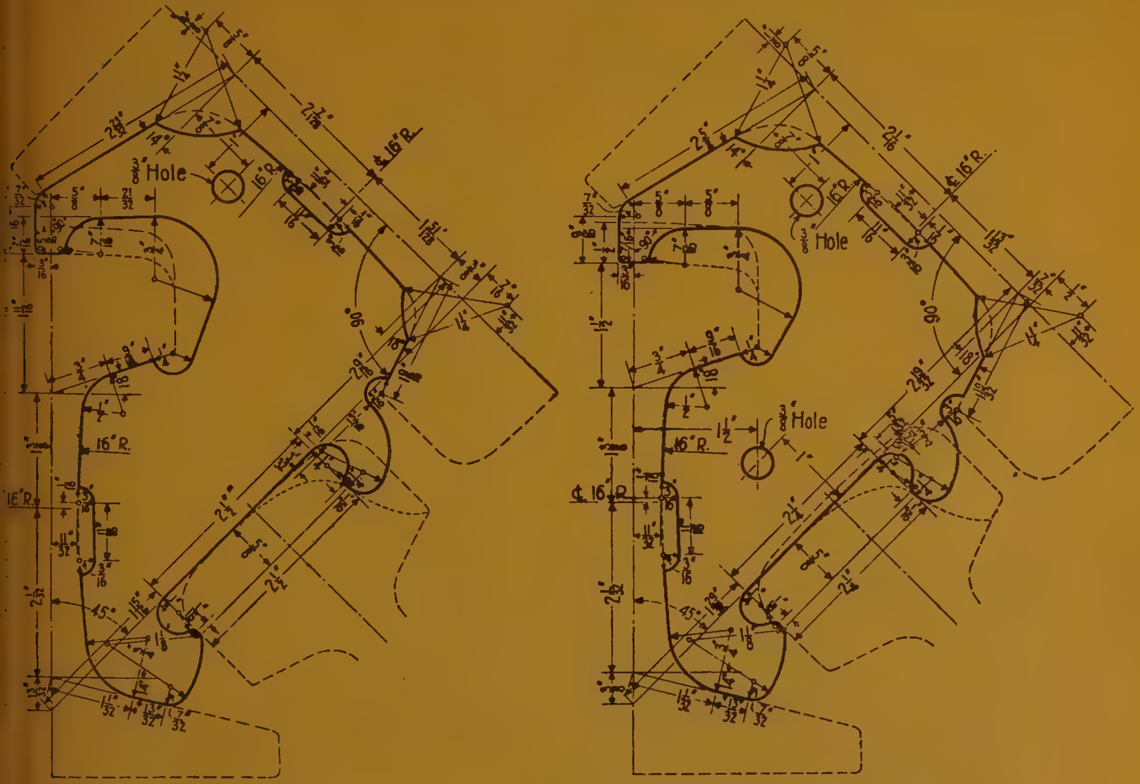
The marking shall be made by deeply cut characters in the positions shown.

No. 3 fit gauge.

Fig. 3 (part 1). — Pennsylvania Railroad System.
Standard worn rail classification gauges for 130 lb. P. S. rails.

The inclination is usually 1 in 20, though in other cases 1 in 40, and 1 in 44 have been used. The standard wheel-tread taper of the American Railway Association is 1 in 20, but the New York Central Lines have adopted 1 in 38, and the Baltimore & Ohio Railroad from entirely different reasoning 1 in 13.

The Union Pacific System from theoretical reasoning thinks that rail breakages should be reduced by inclined rail on account of less eccentric bearing, while the New York, New Haven & Hartford Railroad does not think breakages are increased by rail laid vertically. The Chicago, Milwaukee & St. Paul Railway has not observed that there are more breakages laid vertically, but thinks that rails inclined 1 in 20 do not wear as rapidly from tread or flange, and are easier to hold in line and gauge.



No. 1 fit gauge.

No. 2 fit gauge.

Fig. 3 (part 2). — Pennsylvania Railroad System. — Standard worn rail classification gauges for 130 lb. P. S. rails.

Some of the engineers of the Pennsylvania Railroad System believe that split head failures are reduced to some extent by inclination.

Rail canting is being practised by quite a number of companies in North America, either as a fixed standard, or partially for certain kinds of track, but it is never carried through the frogs and switches of turnouts.

Quite a controversy about the merits of the plan has arisen, and the Committee on Stresses in Railroad Track of the American Railway Engineering Association and the American Society of Civil Engineers has been engaged in making track measurements of both kinds, vertical and inclined, with its instruments in order to see if new data of consequence may be obtained.

In an investigation on the subject by one railroad, the problem was laid down in ten points of advantage for inclined rail, each of which has been commented upon in answer :

POINT 1.

There is an appreciable lengthening of the life of ties accomplished by canting the rail so as to bring the bearing of the wheel as nearly as practicable in the center of the rail head, as it is clear that the tendency for rails to cut into the tie, requiring an additional amount of adzing, is avoided.

Comment on point 1. — The reasoning in this answer is unsound, because the avoidance of cutting of the tie plate into the tie is brought about by using one of suitable size and properly proportioned inside and outside of the rail without any regard to the question of canting. Such avoidance has been brought about with flat plates many times by the use of a suitable size and properly proportioned plate combined with adequate maintenance. In fact, the tendency to cut into the tie at the outer edge of the tie plates is promoted by canting the rail instead of diminishing it, as shown by diagrams illustrating the lines of resultant force produced by a heavy locomotive when passing around curves of 3° and 6° respectively. These lines were determined by a study of the locomotive tests to determine outward pressure, when rounding curves, of the new designs of electric locomotives and by mathematical development. Attention to this fact was called in the following words :

> I call attention also to a part of the problem which has not usually been mentioned, the theoretical advantage of the axial center bearing on the rail head by canting the rail is realized only when the rolling stock is standing still with new wheels on new rails or when running without side lurching. The latter is a very rare condition, as there is nearly always a side thrust on the rail, even on tangent, and in the case with our lines with large per cent of curvature, the side thrust is very important. The vertical load and side thrust produces a resultant pressure which falls far outside of the center of the vertical axis of the rail, and with center bearing on the rail this position of the resultant pressure is at a greater distance from the center than when there is a bearing between the center and the gauge of the rail head. What, therefore, is gained by a center bearing with the inclined rail is largely lost by additional distance of the line of resultant pressure from the center. Information on this point has been carefully worked out in *American Railway Engineering Association Proceedings*, vol. X, part II, 1909, p. 1432.

Instead, therefore, of the value of canting being greater on curves, as against the tendency to cut ties, the condition for cutting is aggravated.

POINT 2.

The wear on the head of the rail will be more symmetrical and probably the life of the rail will be lengthened, especially on curves, by canting the wheel bearing as nearly as practicable on the rail head.

Comment on point 2. — With worn wheels and rail heads, which is the prevailing state of affairs, the advantages which might arise from a center bearing on the rail head are very theoretical and indefinite. In some cases where the wear on the rail head has been very uneven, the cause has been poor maintenance with an improperly proportioned tie plate on the low rail of a curve, which must bear more than its share of the weight of a slowly moving freight train around a curve which is superelevated for the higher speed passenger traffic. With all of these years experience with upright rail we know very well that for the most part the wear on the head is quite symmetrical and even. This has been well illustrated by prints of rail sections which have been in service for a long time. Upon the receipt of copies of these prints by a chief engineer, he wrote « In looking at the sections of low rail, I am surprised to see how in many cases the wear on the top of the rail head had been on lines closely parallel with the original top, and so I am writing to ascertain whether the rail was laid with flat or inclined plates. » To which the reply was made that they were laid with our standard flat tie plates with the high rail elevated 1 1/2 inches. Rail, therefore, may be found in the track with any degree of uneven wear on any kind of tie plate according to the lack of proper maintenance.

Point 3.

Canting of the rail counteracts to some extent the side pressure of the wheels, especially in running around curves, and also the side blows on tangents caused by the nosing of engines.

Comment on point 3. — This is unsound reasoning, already commented upon in point one. The claim that canting of rail reduces the wear on outer rail on curves very materially, which would follow from this, has not been substantiated by tests we have conducted and quoted in previous communications. Rail wear and pressure on the outside rail is due to flange of the locomotive wheels changing the direction from a tangent around the curve, and certainly is not affected by inclination. The two subjects do not belong together mathematically.

Point 4.

Canting will remove some of the stresses in the rail by the wheel riding over the web in place of one side, suggesting the conclusion also that transverse fissures may be due to the eccentric bearing on the side of the head which would be hindered by the canting. Rail breakages on one division as against those of another division are quoted to substantiate this idea.

Comment on point 4. — Transverse fissures are not caused by the traffic borne by the rails, but by defects in some of the processes of manufacture as pointed out in numerous reports of the results of work at the Altoona Laboratory. They are developed in service by the wheel loads, and the heavier the wheel loads and the greater the tonnage of traffic, the more rapid the development in all probability. The idea that transverse fissures may not occur with center bearing on the rail is shown to be incorrect by reports of rail failure investigations by the Altoona Laboratory, Nos. 3589 and 3590. These reports also make the statement that the internal cracks were probably developed at the time of rolling.

Point 5.

Rail with inclined tie plates holds the gauge better.

Comment on point 5. — This is a fallacy, as already explained in point one, as the gauge can be securely and properly held by an adequate number of spike fastenings. In fact, the experience of the French railroad systems discloses the fact that especially on tangent lines there is a tendency to excessively tight gauge with inclined tie plates.

POINT 6.

There is less cost in maintenance.

Comment on point 6. — No information of record has been furnished to support this statement with proof.

POINT 7.

By having the center bearing it is thought that here is less battering of rail joints.

Comment on point 7. — No evidence of this has ever been collected, but it is not believed that inclination of the rail has any appreciable effect in reducing battering, which is more likely to be the cause of poor maintenance combined with weak joints. Experience over many years has been that it is entirely possible to maintain first class and most excellent track with rail laid vertically, which has always been the practice until recently. The experience of other companies has been the same.

POINT 8.

Inclining the rail does not increase the friction of moving loads.

Comment on point 8. — This is a negative advantage, as it is not understood that rail laid vertically does that either.

POINT 9.

The universal desire of those favoring rail inclination is that such inclination should not be carried through turnouts on account of requiring considerable expense in the construction of special devices without justifiable results. The claim is made that the change from canted to vertical position is so slight and so easily accomplished that careful observation must be made to determine where such changes occur. It is stated that this change has been made on curve where one-half of the curve was laid with canted tie plates and the other half with the flat tie plates.

Comment on point 9. — This looks like a rough and unbusinesslike way of dealing with the problem and it is only in the United States and Canada that such looseness in construction has been practised. In England and Europe, where the practice originated, it has been the custom to carry the inclination through the turnouts.

POINT 10.

As the top inclined surface helps the kicking out of the tie plate by wedge action, the shape of the bottom of the plate deserves attention, and the belief is expressed that a multiplicity of spike holes in the tie from the use of anchor spikes is more destructive and lessens the life of the tie much more than the use of a tie plate with properly designed corrugations on its base.

Comment on point 10. — The best answer to this is the satisfactory result of the use of such well spiked tie plates for many years on one of the railroads, and the fact that although the original design of tie plate, the « Servis », had ribs for engaging in the tie, it has long been recognized by railroads that such a tie plate was objectionable and the use of that style has been on the decrease.

Effects of gradients.

Wherever trains make frequent stops, the rail is more worn than at other places, due to the application of the brakes, sometimes locking the wheels; and the punishment of the rail is more severe the greater the starting effort, which frequently results in slipped drivers causing damage to the rail head by burning it in uneven spots, which may be the origin of fractures. These effects are independent of the grade, level, ascending or descending, except in so far as it checks brake application. Places where frequent and regular stops are made are water and coaling stations, passenger stations, and sidings, and frequent stops are made likewise at signals. It is the general observation that there are more breakages on a falling than a rising gradient on account of the high speed of trains, especially near the lower end of the slope, as the high speed brings into greater action the forces due to excess counterweights on drivers, and badly worn wheel treads. Three roads however, the Wabash, Illinois Central, and Chesapeake & Ohio, are inclined to think that breakages are more numerous on the rising gradient.

Effect of sleeper-spacing.

There are no records on the relationship between rail breakages and sleeper or cross-tie spacing, because closer spacing has been brought about by the necessity for additional bearing area upon the soil, as well as from the desire to postpone rail renewals with a heavier weight of rail. It has been considered, therefore, that the lesser spacing made a stronger track with the same weight of rail.

Many mathematical studies have been made to determine the right weight and section of rail, with predetermined spacing of ties, for carrying given loads with safety, and they have usually indicated that a lesser weight of rail is ample for the purpose rather than the one already indicated by the service performance as necessary. This is undoubtedly due to the inaccuracies of manufacture as well as to the uncertainty of assumptions concerning the action of a loose track structure on a yielding road-bed or formation.

Effect of corrosion.

There are only two conditions under which rail is seriously affected for corrosion, the condition of use in wet tunnels, and the condition of use in tracks over which is hauled a large tonnage of refrigerator traffic in cars not yet provided with brine retention receptacles.

The railway engineers have had a controversy on this subject for many years with the mechanical engineers, but finally in 1909, after conducting an eight-day test at the Armour Car Line Shops, Chicago, the Committee of the American Railway Engineering Association (1) considered itself justified in making the following recommendations:

1. All salt-water drippings should be retained in the ice tanks, and drained off only at icing stations.
2. The total capacity of drain openings should not exceed the capacity of traps, and the capacity of drains and traps should be sufficient to release all drippings within the time limit of icing the train.

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(1) *Proceedings of the American Railway Engineering Association*, vol. 12, part. I, 1911.

3. The mechanism adopted for handling drain valves should be simple and positive, and so designed as to insure closing the valves before hatch plugs can be returned to their places.

4. Salt drippings should be conducted from ice-tanks through the drain-valves above described and thense to the outside of cars through the regular traps and drain-pipes.

These recommendations were accepted by the Master Car Builders' Association (now the Mechanical Division of the American Railway Association) in 1910, and after some years of further consideration of details made the following statement in 1921 :

Salt-water Drippings : Conference bas been held with representatives of the principal interests using brine valves and it is the opinion that the various devices now used will, with proper maintenance, perform their functions, that the users of such devices are fully advised as to the necessity of same and should be notified that they must have all cars equipped with brine tanks by 1 January 1922, and that no further extension of time will be granted after that date. It is recommended that paragraph (*f*) of Interchange Rule (3) be modified to correspond with the above.

Rule (3-*f*) then became as follows :

After 1 July 1922, no car carrying products which require for their refrigeration the use of salt with ice, and which are equipped with brine tanks will be accepted in interchange unless provided with suitable device for retaining the brine between icing stations.

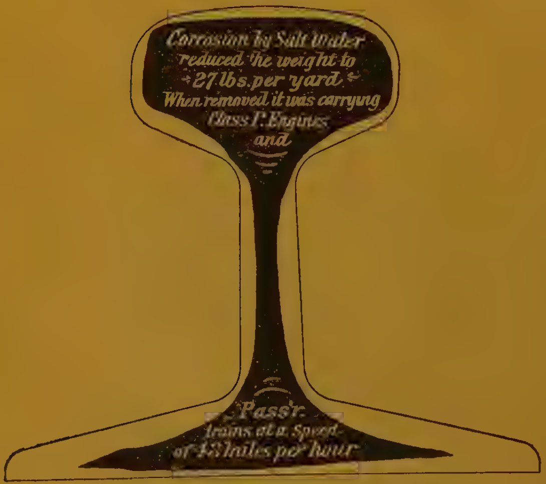

Fig. 4. — Pennsylvania Railroad System.

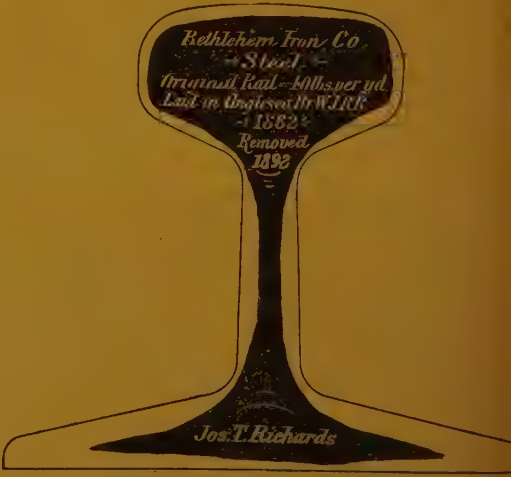
Bethlehem Iron Co
Steel
Original Rail – 60 lbs. per yd.
Laid in Anglesea Br. W.J.R.R.
1882
Removed
1892
Jos. T. Richards

Fig. 5. — Pennsylvania Railroad System.

The time was further extended to 1 January 1924, but it was understood that no additional extensions would be granted.

It is hoped, therefore, that damage to rails by brine will disappear in due course. The remedy for damage to rails in tunnels is to provide better drainage where possible and stop the seepage, or renew the rails more frequently.

In this connection the illustration of the obverse and reverse of a rail section cut from a rail at one time in use on a branch line of the Pennsylvania Railroad System near the Atlantic coast shows an excessive amount of corrosion from the influence of salt water. It shows further a very small rail section on which a heavy 4-4-0 passenger locomotive with axle-loads of about 35 000 pounds was carried at a considerable speed (figs. 4 and 5).

Service rolling-effect of wheels.

The effect of work done on the rails will be considered in connection with transverse fissure failures.

Effect of bolt-holes.

Bolt-holes must not be too close to the rail ends, nor too large, the limitations having been reached by experience. The drilling recommended by the American Railway Engineering Association for joint bars is 5-1/2 inches between centre holes, with spacing of 5-1/2 inches for succeeding holes. This allows the centre of the end hole of the rail to be about 2-21/32 inches from the end. There are many variations from these as the accomplishment of a society recommendation requires a long time. The bolt holes for 130-pound P. S. rail are 1-3/16 inch diameter, and for 136-pounds Lehigh Valley 1-5/16 inch diameter. There are no data concerning the effect these sizes have on breakages. The subject of rail breakage within the limits of the length of joint bars is quite complicated, but it is considered generally that meager maintenance is the predominant cause.

Rail breakages at joints.

The relative proportion of failures within the limit of the length of the joint-bars to those in the remainder of the rail varies widely on different railroads, depending upon perfection of track and joint maintenance, the density of the traffic, and the design and material of the joint-bars. On heavy traffic railroads it is about 50 %. The form of record mentioned in the questionnaire, « breakages per unit of length of rail covered by the plates », is not used in North America. The form used is : « Failures in-side and failures out-side of the joints. »

Differences from this proportion are named by several railroads as follows :

TABLE 4.

Proportion of rail failures in-side and out-side of joints.

RAILROAD.	Proportion of rail failures within the joints.
Wabash	75 °/₀
Baltimore & Chio.	40 °/₀ in rail under 10 years. 53 °/₀ in rail over 10 years.
New York Central	1 failure in joint to 30 outside.
Chicago, Rock Island & Pacific	28 °/₀
Central Railroad Company of New Jersey.	30 °/₀
Lehigh & New England. . .	19 °/₀
Illinois Central	15 °/₀

The low proportion of failures within the joints on the New York Central Lines is attributed to the use of centre-supported three-tie ordinary angle-bar joint 36 inches long (new design 38 inches), which is used by no other system.

The designs of joints are very diverse, but their differences can be overcome largely by degree of perfection of maintenance.

Trailing-versus facing end.

No records are kept by railroad companies of « the relative proportion of failures in the trailing end which the wheel runs off, and the facing end on to which the wheel runs », but universal observation has shown it to be a fact that the failures at the *receiving* end rail are greater than at the *leaving* end rail.

4 — Breakages attributable to defects in the metal in rails.

Changes to meet severity of service.

Up to this point rail failures have been considered from the criterion of exigencies of service. The rail failures have been inspected with the idea that the design of the track, and the formation on which it is laid are at fault, and if failures occur they are due probably to the rail being too much worn, the yielding of the road-bed, laying the rail axially or inclined from the line perpendicular to the tie, the effect of gradients, the distance between rail supports affecting the strength and stiffness of the rail as a beam girder, the destruction by corrosion, and the design of the joint bars. The inference might be that after a careful study of each of these destroying forces, the engineer should be able to apply the remedy which would be improvement in the rail strength and stiffness by greater weight and suitable distribution of material, closer spacing of cross-ties (or sleepers), and a higher standard of maintenance, especially at the joint. All these have been done, and have had to be done over and over again as the density of traffic and the axle loads of rolling stock increased, until from iron rail weighing 40 pounds per yard (and even ordinary flat iron straps on timbers) we have today the high-carbon Open-hearth steel rails of 130, 135 and 136 pounds per yard.

Inasmuch as economy of railroad operation depended more and more upon the quantity of freight hauled in one train, great energy has been devoted to the increased capacity of the locomotive unit and the goods vehicle; but, after a track has been built, it requires many years for economic replacement, and this work of replacement has been behind the advancing weights of rolling stock for the greater part of the time.

The locomotive, no longer of large enough tractive effort, could be relegated to a portion of a railroad system where it would be proportioned to the business requirements, but the obsolete track could not be torn up to follow it and be replaced with stronger construction in a day.

Historical aspect.

As this Congress is being held in London to commemorate the Centennial of the establishment of the plan for transportation on land which has been the life and comfort of world civilization, it is befitting to draw a picture in outline of a hundred years progress in the construction of the roadway portion of that system, and accordingly some pages will be written to describe the several periods of the investigations and research in connection with the rail element of the roadway, in order to keep it adequate for the service imposed.

This review of the work of the railway engineers leads us by natural stages to the responses to the questionnaire of the reporters.

= Introduction of steel rail.

With the more and more rapid advancement in density of traffic, speed of trains and weight of rolling stock, it began to be apparent that the material from which iron rail were made was not homogeneous or reliable always, or of sufficient toughness and ductility.

Therefore, in 1862, Mr. J. Edgar Thomson, President, Pennsylvania Railroad, while in England investigated the value of the different steel rails then being put on the market for the first time, and decided to expend $60 000 for the purchase of 400 tons for trial. This order was followed by others, the general statement of the different lots being given in table 5.

TABLE 5.

PENNSYLVANIA RAILROAD.

Earliest lots of steel rail purchased for trial.

Year.	Lot No.	Quantity in tons.	Kind of steel.	Weight per yard.	Manufacturer.	Place laid.
1864	1	157	Crucible.	56	Chas. Cammel & Co. Cyclops Cast Steel.	Altoona & Pittsburgh. In busy sidings.
1865	2	100	Crucible.	56	Chas. Cammel & Co.	Philad. & Altoona. In sidings.
1865	3	30	Bessemer.	56	John Brown & Co.	Philadelphia.
1865	4		Bessemer.	56	Chas. Cammel & Co.	Pittsburgh.
1865	5	27	Bessemer.	56	John Brown & Co.	Altoona siding.
1865	6	60	Bessemer.	56	John Brown & Co.	West Philadelphia & Harrisburg.
1865	7	37	Bessemer.	56	Chas. Cammel & Co.	West Philad. siding
1865	8	87	Bessemer.	56	Chas. Cammel & Co.	West Philadelphia.
1866	9	5	Dodds steel rails.	64		West Philad. & Altoona.
1866	10	26	Steel head rails.	64	Trenton Iron Works.	West Philadelphia yard main track.
1866	11	1 003	Bessemer.	67	Chas. Cammel & Co.	Philadelphia Middle & Pittsburgh divisions.
1866 1867	12	491 502	Bessemer.	56	John Brown & Co.	
1867	14	183	Bessemer.	67	Chas. Cammel & Co.	

Note. — The first commercial rolling of Bessemer steel rails at the Cambria Works was on order from the Pennsylvania Railroad.

A. S. C. E. Committee of 1873.

It will be noted that the weight of rail was increasing continually within a short period, but trouble from rail failures continued from the rapid increase in severity of business service, which seemed to outstrip the power for economic replacement of the rails, and for the first time, in 1873, the American Society of Civil Engineers entered upon a study of the problem by appointing a committee (¹) on 8 January, to report on forms, sizes, manufacture, tests, endurance, and breakage of rails, and also comparative economy of steel and iron rails.

* * *

The several reports are in *Transactions, American Society of Civil Engineers,* vol. III, 1874, vol. IV, 1875, and vol. V, 1876, final. The chairman prepared the reports which were severally presented, 10 June 1874, 5 May 1875, and 15 June 1876. They were accompanied by a *Memoir on rails,* by Ashbel Welch, 10 June 1874, and *Notes on the weight of rails and the breaking of iron rails,* by O. Chanute, 15 July 1874. The final report calls attention to « a valuable contribution by Mr. Frederick J. Slade, published in *Railroad Gazette,* 27 November 1875. For a very easy method of comparing the practical values of rails or other things of different durability they refer to a paper by the chairman on the « Comparative economy of steel and iron rails », published in the *Journal of the Franklin Institute,* July 1870, and its formulæ made use of in the first report of the Committee.

Design of « Tee » iron rail.

Almost to this period, iron rail was being used by American Railroads of the « I-beam » or « tee » type as it is now called, which (¹) was designed in 1830 and first used by Robert L. Stevens, president and chief engineer of the Camden & South Amboy Railroad & Transportation Company.

He had been ordered by the Board of Directors to visit England to inspect and report upon railroad matters there and purchase « all iron rail » which the management of the Company preferred to the wooden rail plated with strap iron, and it was during this voyage that he designed the first rail ever rolled with a base, whittling several cross-sections out of wood, which he obtained from the ship's carpenter.

« He was familiar with the Birkenshaw rail, with which the best English roads were then being laid » (the T-section set in cast iron chairs, almost of the same profile as the English wrought iron rail laid on the Portage Railroad, Pennsylvania in 1833), « but he saw that, as it required an expensive chair to hold it in place, it was not adapted to our country, where metal workers were scarce and iron was dear. He added the base to the T-rail, dispensing with the chair, thus making it I-beam in form. He also designed the *hook-headed* spike (which is substantially the railroad spike of to-day) and the *iron tongue* (which has been developed into the fish-bar), and the rivets (which have been replaced by the bolt and nut) to complete the joint. »

The design and letter of invitation for quotation are presented herewith in « fac-simile » (Exhibit 3) from the *Transactions, American Society of Civil Engineers,* vol. XXII.

The bearing enlargements of the base were found to be impracticable, and the

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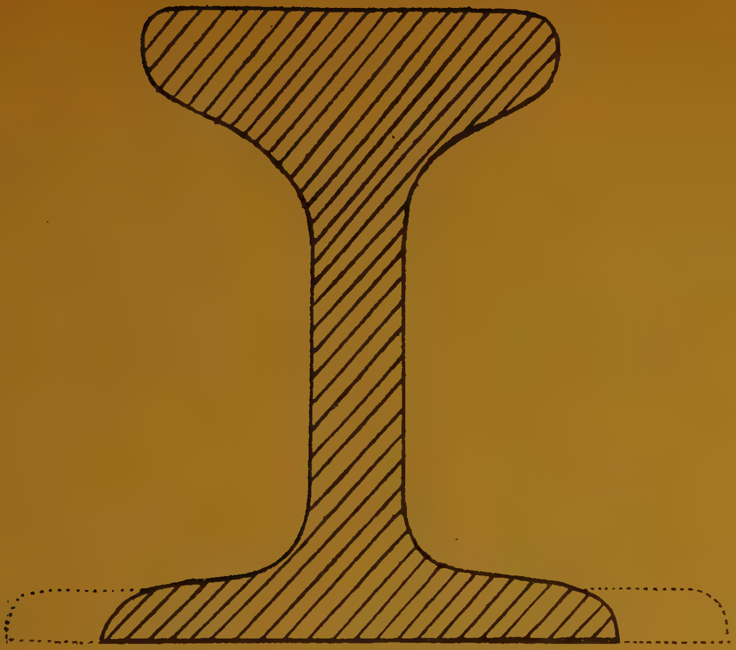
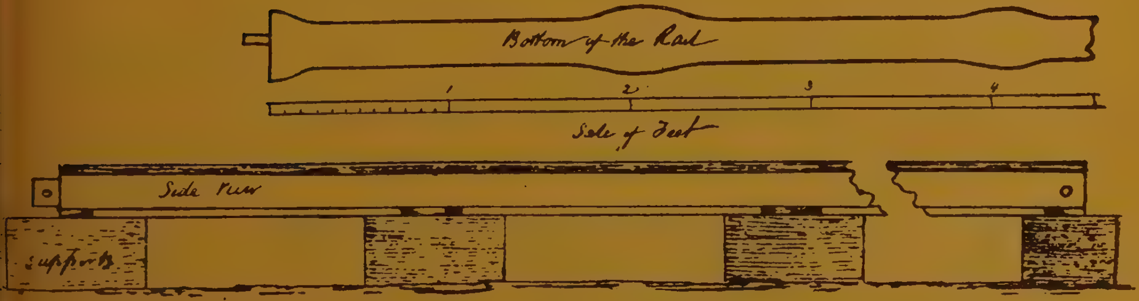
(¹) Committee consisted of Ashbel Welch, C. E., chairman, M. N. Forney, M. E., O. Chanute, C. E., and I. M. St. John, C. E.

(¹) *Transactions, American Society of Civil Engineers,* vol. XXII, 1890 : « Development of the American rail and track, by J. Elfreth Watkins.

EXHIBIT 3.



Full size with projections of every 2 feet in the bottom flange, 3/4 of an inch by 4 inches.



Liverpool, November 26 1830.

Gentlemen,

At what rate will you contract to deliver at Liverpool, say from five to six hundred tons of Railway, of the best quality iron rolled to the above pattern in twelve or sixteen feet lengths, to lap as shown in the drawing, with one hole at each end, and the projections on the lower flange at every two feet. Cash on delivery. — How soon could you make the first delivery, and at what rate per month until the whole is complete. Should the terms suit and the work give satisfaction a more extended order is likely to follow, as this is but about one sixth part of the quantity required. Please to address your answer (as soon as convenient) to the care of Francis B. Ogden, consul of the United States at Liverpool.

I am
Your obedient servant
Rob^{t} L. Stevens
President & Engineer of the Camden & South Amboy Rail Road & Transportation Company.

base was made of uniform width of 3 inches. A 36 pound rail was rolled by the Dowlais Iron Works in Cardiff, Wales, and laid in 1831. The next shipment weighed 42 pounds per yard.

In view of the recommendation for flat topped rails and cylindrical wheels made by D. J. Whittemore (1), chief engineer, Chicago, Milwaukee & St. Paul Railway in 1889, it is noteworthy that the top surface of the head of this rail is flat.

Cross-tie railroad.

It is interesting to point out in this connection that the Camden & South Amboy Railroad & Transportation Company « was the first in the world to be laid according to the present American standard », that is, with cross-ties and hook-spikes, as shown in the illustrations from *Transactions, American Society of Civil Engineers*, vol. XX (fig. 6).

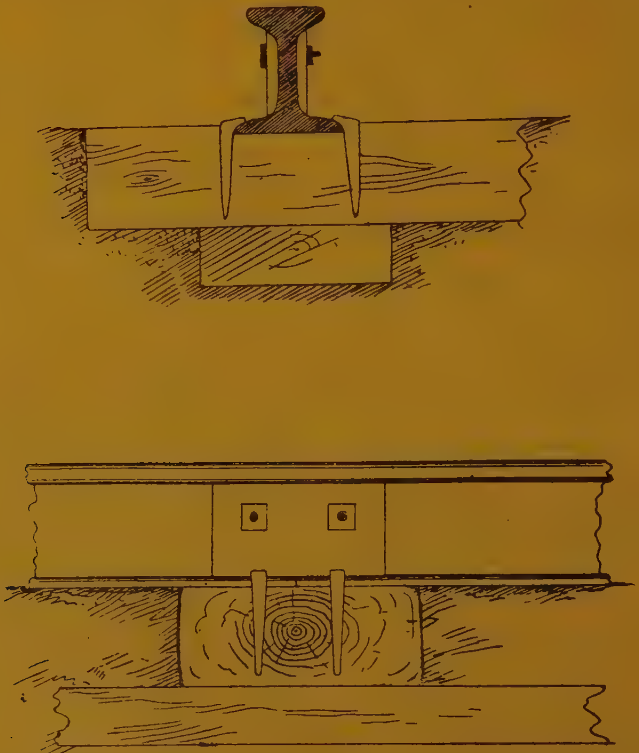


Fig. 6. — Camden & Amboy Railway Standard — 1837.

The poor quality of iron rails later led to the development of this rail into the pear-shaped profile.

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(1) *Transactions, American Society of Civil Engineers*, vol. XXI, 1889 : « Cylindrical wheels and flat topped rails for railways », by D. J. Wittemore.

Design of « Tee » steel rail.

The reports of the Committee of 1873 are important because they fixed the general type of steel rail design for the principal railroads of the Atlantic Coast south of New York, which was used for many years. This type was, in 1865 and later, the design chiefly of Ashbel Welch, chairman, who was executive officer and engineer of the system of railroads occupying the central part of the State of New Jersey between Philadelphia and New York, subsequently known as the United New Jersey Railroad & Canal Company, and leased to the Pennsylvania Railroad Company 1 July 1871. His company included the Camden & South Amboy Railway & Transportation Company, whose president and chief engineer, Robert A. Stevens, had designed the iron tee-rail. He was vice-president of the American Society of Civil Engineers in 1881, and president in 1882, dying in office. He was the originator of the heavy head steel rail, his principle being to put all the mental possible, about 50 %, into the head and as little as possible anywhere else. It was considered that the Bessemer steel rail settled the problem of strength, having so much greater limit of elasticity than the iron rail. « A steel rail wears out; an iron rail is knocked to pieces before it is worn out » ... « Our rails do not give out from want of strength, but from injury to head, not always perceptible to the eye ».

The elements of rail design were stated as follows :

> A rail has two principal functions or classes of functions; acting as a beam or girder, to carry the heaviest weights between the most distant actual supports, without straining the metal beyond the limits of its elasticity; and to distribute the weight bearing on one point of the rail among the adjacent supports. The first part of this function requires strength, the second stiffness. The second class of functions or duties of the rail is to resist crushing, and to endure wear. The first of those require hardness and breadth of surface, the second hardness and area of section to wear off, or consumable area. We shall consider the rail as divided into two parts, the consumable and the residual; the latter including what is left of the head after the consumed part is worn off, and all below it. The endurance of the rail, if of good quality, depends on the consumable. The residual must have the requisite strength and stiffness after the other is worn off. These should be carefully distinguished. What is good for one is often bad for the other.

The value of width of head too is fully recognized in the report, as may be seen from the excerpt :

> In the former report, great breadth of head was recommended, because with a given weight the more it is distributed, the less the injury done by it. But it may be objected that as the wear on the side of the head in some cases is nearly so much as on the top, the diminished depth necessary to give increased width with the same amount of metal, counterbalances the advantage of the breadth. But the endurance of inury from the pressure of a given weight on the top is under some, perhaps not very unusual conditions, as the square of the surface compressed, while the endurance of shearing on the side is probably only directly on the surface. Besides, the wider the head the greater the aggregate amount of service.

Contact area of wheel and rail.

The necessity for large bearing area on the head was discussed by Octave Chanute of the committee in his « Notes » attached to the report, and in 1864 he seems to have been the first engineer to attempt to measure the area of surfaces of contact between rail and wheel. He « entertained the opinion that the assumption of any fixed relation between the weight of rail and the maximum load borne by one pair of wheels passing over it was milleading and fallacious. A simple consideration of the pressure on the surfaces in contact between the driving wheels of the locomotives and the rails will make this apparent. If the wheel and rail were both inelastic, the contact would be a line, and the pressure would be infinite. Being elastic, however, they both yield a little, and the contact becomes a surface. »

He measured this surface « by jacking up simultaneously both wheels of a pair of drivers, and introducing between them and the rails a sheet of thin tissue paper, underlaid by a black sheet of thin manifold copying paper. By lowering the wheels upon the paper, and allowing their full weight to rest thereon, a very good impression of the surfaces in contact was obtained. » They averaged about 3/4 inch across the face of the rail, and about 3/8 inch along its length; giving an area of 9/32 of a square inch, on which a weight of 9 000 pounds will exert a pressure of 35 555 pounds per square inch, and 11 000 pounds, pressure of 39 111 pounds per square inch.

Some of the measurements showed intensity of pressure per square inch of 86 000 pounds under a weight of driver of 11 175 pounds, but were generally 27 000 to 35 000 pounds.

The pressures are *static*, and as ordinary wrought iron begins to crush at about 38 000 pounds to 40 000 pounds to the square inch, the weights noted, when put into motion, are pretty sure to smash down any material so soft as ordinary bar iron. While the maximum weights on the wheels, therefore, should undoubtedly govern the hardness of the material in the head of the rail, it has no relation to the *weight* of the rail, except so far as this results from its necessary form and proportion as a girder to carry and distribute the weight to the supports, and this again is modified by the distance these may be spaced apart...

If these premises are correct, it follows that the adding of weight to an iron rail, already sufficiently stiff to carry the load, would only ensure its more rapid destruction, by making it too rigid to yield slightly under the wheel, and perhaps by preventing such slight deflections between the supports, as is found admissible in practice, and which by curving the rail to some assimilation with the wheel, probably increases slightly the areas in contact, and so diminishes the intensity of the crushing pressures.

He says, therefore, « where locomotive driving wheels are loaded to 11 000 pounds or over, the rails should be of steel ».

Thin base.

This point of stiffness of rail section was regarded by the committee in the report as less important than amount of metal in the head, and the width of head for bearing, and the problem to the members was that :

Too much stiffness actually diminishes the longevity of the rail.

The controlling consideration in England is strength on account of wide spacing of ties, while here it is wear by reason of the shorter spacing.

Therefore, the base of the rail was made as thin as possible, additional metal being regarded as wasted, which thought prevails with some of the administrations to the present day. It was recommended that 3/16 inch is sufficiently thick for the edge of the base and the point is commented upon as follows :

It is objected to this very thin stem, and especially to this very thin edged base, that it cools so rapidly in rolling as to make the metal brittle; and that the head cools so much more slowly than the rest as to create a permanent strain. Of course, this tendency exists, and it requires some care to prevent its reaching a practically injurious extent. According to the argument, not only such rails ought to break in two, but especially the thin edges of the base ought to break off — but they do not.

Fishing angle.

The fishing angle was made 4 to 1 or about 14°, which is recognized today as the most suitable by the American Railway Engineering Association. It was a vital and important change from the pear-shaped head of the iron rail, copied into the early designs of steel rails.

The report stated that « forms of rails on the same principle as those recommended by the committee have been adopted on three of the great railroad systems, the Erie, Lehigh Valley, and the Pennsylvania, and that the Pennsylvania has also adopted the plan of a deeper head for main lines on nearly the same base as a shallower head for branches; the base for main lines is 4-1/2 inches ».

Rail-fibre elongation by wheels.

A very important statement on breakage of rails was made by Mr. Welch as follows :

We call attention again to the elongation of the top of the rail by too great weight on a wheel in proportion to the bearing surface, and the hardness of the metal, by which a permanent strain is created on the rest of the rail, perhaps gradually snapping the extended fibres or somehow weakening the metal, resulting in ultimate fracture.

We also repeat that this is partially remedied by greater width of the top of the rail.

But why do rails break in winter especially ?

1° Because the material is, as most of the Committee think bas been proved, more brittle in very cold weather. According to experiments reported by Sandberg, specimens requiring a drop to fall 39 feet to break them, with the thermometer at 84°, were broken with the same drop falling 11 feet, with the thermometer at 10°. Different kinds of iron and steel vary very much in this respect. Steel, though more elastic, does not wire-draw like iron. Iron does not wire-draw so much when cold, but it may be questioned whether the limit of elasticity in iron or steel is lowered by cold. If it is not, then cold alone would not endanger the rail, but inordinate strain must be an essential condition of fracture;

2° The road-bed heaves irregularly, causing the rail to bear on a few points far apart;

3° The road-bed being frozen hard becomes inelastic, and also high points are not lowered to the level of other supports by the weight;

4° The top of the head being elongated, and a permanent longitudinal strain thus created cooperates with the other causes in producing fracture;

5° Insufficient allowance for contraction by cold may cause a longitudinal tension acting against the fish-bolts.

This contains the germ of the present day theory of rail breakage, especially in connection with the development of the type known as *interior transverse fissure.*

It also recognized thus early the ill effect of the frozen condition of the road-bed on rail breakages in the winter time.

Requisites of rail design.

When vice-president of the American Society of Civil Engineers, Mr. Welch again reviewed this problem at the 13th Annual Convention, 15 June 1881, under the title of « Comparative economy of steel rails with light and heavy heads ». He said :

(1) In planning a steel rail, the first thing to be done is to fix upon a residuary rail strong enough to carry safely the machinery and the load that are to run over it. Of course, the weights, speeds, springs, ties and road-bed, and possible increase of weights and speeds, must be taken into consideration. So many unknown quantitites affect the question of strength required, that it cannot be found by calculation alone, but by experience, under the same or similar circumstances. The base should be broad enough not to crush or wear out the tie, and its area a little greater than that of the residuary part of the head. The stem should be as thin as experience has shown to be perfectly safe (for its thickness adds little to the strength of the rail); no existing circumstances require more than half an inch; but the usual height could be increased with advantage, for that would give opportunity to increase the strength of the splices.

The size of the consumable part of the rail will then be governed by the amount of traffic expected, taking into consideration the greater wear per million of tons produced by greater weights on a wheel, higher speeds, poorer springs, steeper grades and sharper curves. The wear on a steep grade and sharp curve is sometimes as much as five times the wear of the same traffic on level tangents. Speaking generally, the consumable part of the rail should be proportioned to the amount of traffic, the residuary part to the weight on a wheel.

A small percentage of metal added to the head of most of the steel rails in use adds a comparatively large percentage to their durability. In most cases only about 15 % of the weight of the rail can be worn off from the head, all the rest — 85 % of the whole original weight — being required to carry the load safely. By adding 15 % to the weight of such rails, putting it in the right place, their duration is doubled. On the other hand, interest must be paid on the cost of the additional metal before it comes into use at all during the whole time in which the original unincreased consumable quantity is wearing off. With heavy traffic, endurance; with light traffic, interest, is the weighty consideration.

Numerous rail designs.

This investigation has been reviewed at considerable length, because it was the first united effort of railway engineers to call a halt upon the multiplicity of rail and joint-appliance designs which had been brought into use, and at the time it stated many of the questions of rail design which have been under discussion ever since. In February 1881, in his discussion of a paper (1) by C. B. Dudley, Ph. D., Mr. O. Chanute said :

We had on the Erie Railway, when the

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(1) *Transactions, American Society of Civil Engineers*, vol X.

(1) « The Wearing Capacity of Steel Rails in Relation to their Chemical Composition and Physical Properties », by Charles B. Dudley, Ph. D., chemist, Pennsylvania Railroad Compagny, Altoona, Pa.

new steel section was adopted, 12 patterns of steel rails, 29 patterns of iron rails, and 96 different styles of fastenings. These caused no end of annoyance, delays and expense, in matching or mismatching them, taking up and changing about long strings of rails, and in the large stocks which it was necessary to keep for repairs.

Durability of rail.

It will be noted that the theme of these reports was an economic one, the greater durability of rail, obtaining more years of service, while at the same time the profile of the iron rail, which had come to the end of its capacity for carrying the increasing traffic, was being re-designed of the new and stronger material, Bessemer steel. As its structure was granular instead of fibrous, Mr. Welch saw the opportunity for changing the profile so as to obtain a better support for the joint bars, and locating more of the material in the « consumable » part of the rail. Scarcely anything was said about the chemical composition, which was left entirely to the manufacturer.

Early rail tests.

There were, however, methods of testing the physical characteristics, introduced from England, the earliest rails being purchased there, and they were used on the iron as well as the steel material. The drop test by a weight or tup falling from an established height was the most common, but Mr. Welch considered this might be suitable « in England for testing the rail as a beam and the metal for brittleness and strength, but here not so for wear ». He adopted the plan, therefore, of hammering to destruction.

The earliest written specifications of the Pennsylvania Railroad System which have been found, seem to recognize this idea. They were dated September 1876, and are reproduced herewith as of considerable interest :

PENNSYLVANIA RAILROAD COMPANY.

Specifications for steel rails.

(*September 1876.*)

As it is the desire of the Pennsylvania Railroad Company to have on the roads under their control none but first-class tracks in every respect, and as the rails laid down on these tracks form an important in the achievement of the results, the Pennsylvania Railroad Company have found it necessary to make certain demands in regard to the manufacture of their steel rails, with which the different rolling-mills and rail-inspectors will be required to comply :

1. That the steel used for rails shall be in accordance with the « pneumatic » process, and contain not less than thirty one-hundredths nor more than fifty one-hundredths of one per cent of carbon.

2. That a test bar one foot long and three-quarters of an inch square is to be taken from the head of a rail made from each charge. This bar is to be supported at each end, leaving a space of eight inches between bearings, and by a sudden pressure on the center of the bar, deflected to an angle of eighty degrees from a straight line. This angle will be made the limit between good and bad tests. If the bar bends eighty degrees without breaking, the charge will be considered good; if the bar breaks before bending, or shows signs of fracture at this angle, two more bars are to be tested; if both the bars stand the test, the charge will be considered first-class steel; but if one of them breaks, the charge will be rejected and called second-class steel.

3. The result of the test of each charge of which the Pennsylvania Railroad Company are to receive rails, and of which an official record is kept at each mill, is to be exhibited to the rail-inspector.

4. That the number of the charge and place

and year of manufacture shall be marked in plain figures and letters on the side of the web of each rail.

5. That the section of the rails rolled shall correspond with the respective templates issued by the Pennsylvania Railroad Company, showing the shape and dimensions of the different rails adopted as their standard.

6. That the space between the web of the rails and template representing the splice bar, shall not be less than one-quarter of an inch, nor more than three-eighths of an inch.

7. That the weight of rails shall be kept as near to standard weight as can be demanded after complying with Section No. 5.

8. That the circular holes one inch in diameter shall be drilled through the web in the center thereof, at equal distances from the upper surface of the flange and lower surface of the head, and three and fifteen-sixteenths inches from the end of the rail to the center of the first hole, and five inches from the center of the first hole to the center of the second hole.

9. That the lengths of the rails at sixty degrees Fahrenheit shall be kept within one-quarter of an inch of the standard length, which are 30-feet, 27 1/2 feet, and 25-feet. That not more than ten per cent of the rails of the shorter lengths shall be delivered on any one contract.

10. That the rough edges produced at the ends of the rails by the saw shall be well trimmed off and filed.

11. That rails are so straightened that they will insure a perfectly straight track.

12. In order to get the exact length as mentioned in paragraph No. 9, it is necessary that the rails should be cut off at as near a uniform temperature as practicable, that the blooms should not be detained in the process of rolling, and should go to the saws at a uniform temperature.

The causes of a temporary rejection of rails are :

1. Bad straightening.

2. Imperfect ends which, after having cut off, would give a perfect rail of one of the standard short lengths.

3. Missing test reports.

4. A variation of more than one-quarter of an inch from the standard lengths.

The causes of a permanent rejection of a rail are :

1. A bad test report, showing a deficiency or excess of carbon.

2. The presence of a flaw of one-quarter of an inch in depth in any part of the rail.

3. The presence of such other imperfections as may involve a possibility of the rail breaking in the track.

4. A greater variation between the rail and splice bar than allowed in paragraph No. 6.

By order of the General Manager,

Wm. H. Brown,
Engineer, maintenance of way.

« Chemistry » of rail steel.

It will be noted that the limits for carbon content are named, 0.30 to 0.50, for the company was having trouble with its *steel* rails.

Finally, Charles B. Dudley, Ph. D., chemist, Pennsylvania Railroad Compagny, was assigned to make an investigation which he states as follows :

(1) In the Spring of 1877, the Pennsylvania Railroad Company became so dissatisfied with the average life and wear of the steel rails it was then able to procure, that it determined to make an investigation into the chemical composition and physical properties of steel rails, with a view, first, to answering the question why one steel rail has to be removed from the track after, perhaps, eight month's service, while another lasts ten years; and, secondly, if this investigation succeeded in throwing light on this im-

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(1) « The Chemical Composition and Physical Properties of Steel Rails », by Dr Charles B. Dudley. (*Transactions of the American Institute of Mining Engineers*, vol. VII, 1879.

portant subject, to use this information in securing better rails in the future.

. . . .

It seems to be agreed among metallurgists that the quality of a piece of steel depends upon two sets of circumstances; 1° Its chemical composition; and, 2° The treatment which the metal receives either during or after its manufacture.

. . . .

So that the question with which we started, *viz.,* How shall the Pennsylvania Railroad Company obtain steel rails which shall give satisfactory wear and be uniform in quality ? seems to be resolved into two others, *viz.:* 1° With the present known metallurgical methods in the Bessemer process, what chemical composition shall the Pennsylvania Railroad Company prescribe for its rails ? and 2° What physical tests and inspection shall it apply to secure uniformity of product ?

Twenty-five pieces of steel rails from actual service were carefully analysed for carbon, phosphorus, silicon, and manganese; and were tested in physical qualities, such as tensile strength, ductility, etc., on professor Thurston's Torsional Testing Machine, as being the best means of determining the largest number of physical qualities at a single test.

He found that « phosphorus and silicon seem to harden steel without adding any other desirable qualities, except, perhaps, wear »; and after stating that phosphorus even in very small quantities makes steel brittle, he says, « as to silicon, the less in the rail the better ».

From this study Dr. Dudley recommended :

That the following formula be prescribed for the chemical composition of rails for the use of the Pennsylvania Railroad, *viz.:*

Phosphorus, not above	0.10 %
Silicon, not above	0.04 %
Carbon, between 0.25 and 0.35 % with an aim at	0.35 %
Manganese, between 0.30 and 0.40 % with an aim at . .	0.35 %
Sulphur and copper. .	No specifications.

All other impurities, not more than traces.

That the tensile strength of rails for use on the Pennsylvania Railroad, should be above 65 000 pounds per square inch, and that the percentage of elongation be above 20 %.

With reference to physical tests and inspection, Dr. Dudley examined the following three plans, and recommended the third :

1. The bending test now in use. It seems to me fatal to this test as at pres- square by 12 inches long, is hammered ent conducted that the test bar, 3/4 inch out from a piece of the rail. It is conceded, I think, that in proper hands a piece of steel is changed by hammering. We are, therefore, not testing the steel in the rails, but a different quality of steel. If the present bending test is to be continued, I would suggest that the test bar be cut from the rail head, instead of hammered from it.

2. The drop test. This test was in use for some time on the road to determine the quality and uniformity of the rails purchased. With regard to this test it may be said that unless the foundations are very solid, much of the force of the blow is lost; so that a rail tested under a rickety drop might stand the prescribed test, which, under a firm one would yield. It would seem, therefore, that the drop test, without extreme care and inspection on the part of the railroad company to hold the rail manufacturers up to specifications would give erroneous results. It is due to this reason, as I understand, that the drop test was abandoned.

3. Still another method of testing our rails suggests itself, and that is to ask the rail manufacturers to provide themsel-

ves with and use the same kind of machine upon which the physical tests of the series of rails analyzed have been made, *viz.*, Thurston's Torsional Testing Machine. That this would be the most valuable method of securing uniformity in rails furnished us, will be evident, it seems to me, from a study of the physical tests in the table. It should be stated here that of all the data furnished by this machine, in regard to the physical qualities of metal (which data are given in full for record, in connection with the analyses, in the preceding pages, and are tabulated in the table, we have selected out two, *viz.*, tensile strength and percentage of elongation, as best expressing the value of the steel with our present knowledge of the subject. It should also be stated that the tensile strength given in this report is 94/100 of that obtained by the formula for determining the tensile strength which accompanies the machine, this being found by comparative tensile and torsion tests to most nearly express the tensile strength of this grade of steel.

The specifications for steel rails already quoted had been issued by the Engineer Maintenance of Way in September 1876, and as the specifications remained substantially the same up to 1 April 1885, without any specified limits for chemical elements, and without changing the bent bar test to the torsional test, except that the test piece was taken from the web instead of the head and the details of the test were omitted, it is evident that the recommendations were not adopted.

However, on 11 February 1889, limitations for carbon content were introduced into the 1885 specifications for 85-pound, but not for any less weight than 85-pounds per yard, the range being from 0.45 to 0.55 %, which was considerably higher than Dr. Dudley's recommendation for Bessemer steel.

Chemistry and wear of rails.

(¹) Three years after this investigation, Dr. Dudley resumed the study of rail, but on this occasion « It was thought that an investigation into the relation between the wear of steel rails and their chemical composition and physical properties could not fail to throw light upon a question of vital importance in the management of the Pennsylvania Railroad. » He considered that, « with the improvement in maintenance of way which had characterized the Pennsylvania Railroad during the last five or six years », the removal of rails from the track on account of breaking and crushing had « notably diminished ». He had been « struck with the surprising wear which some of the rail, which would ordinarily be called soft rails, had endured ».

Although not written into its specifications, the Pennsylvania Railroad Company was receiving rails with a carbon range from 0.30 to 0.50 %, and in 1876, in view of unsatisfactory wear had asked the rail makers to raise the lower limit to 0.40 %. Dr. Dudley quotes Mr. Brown, Engineer Maintenance of Way as saying that the higher carbon rails were giving poorer wear than the lower.

After many tests and careful study, Dr. Dudley expressed his decision in the following sentences :

> The conclusion reached (in the first investigation), « as you remember, was that the softer rails are less liable to crush or break in service than the harder ones. Now in this second investigation we find that the softer rails give the better wear ».

(¹) « The Wearing Capacity of Steel Rails in Relation to their Chemical Composition and Physical Properties, by Charles B. Dudley, Ph. D., (*American Institute of Mining Engineers*, February, 1881).

He, therefore, recommended the same chemical composition as in the first report. The following physical test was recommended, and appears to have been adopted in principle in the 1885 specifications :

> The test-pieces shall be cut from the web of the rail and shall be 12 inches long, 1 1/2 inches wide, and 1/2 inch thick. These pieces shall be tested in the manner prescribed in the preceding part of this report, and on all steel accepted these test-pieces shall stand a maximum load of not over 3 000 pounds and shall bend not less than 130° without rupture.

In the discussion of these reports by the rail manufacturers and by metallurgists, the opinion was held, almost unanimously, that the case had not been proved, but needed further investigation. Mr. R. W. Hunt, general superintendent, Albany and Rensslaer Iron and Steel Company was the most pronounced in his opposition to the conclusions reached, citing many contrary indications. He said he had « devoted much time and thought to the effect of silicon on steel, and had become fully convinced that it is a desirable element, like many other good things, requiring to be used with judgment, and also like some other blessings, frequently called upon to shoulder sins not its own ». Neither did he consider Mr. Brown's report that « the rails of higher carbon are giving poorer wear than before the lower limit of carbon was raised » was supported by any authentic analyses. He called attention to one of the rails which had carbon 0.483, phosphorus 0.035, silicon 0.480, manganese 0.782, and stood eighth in sixteen tests. He also « mentioned a rail in the track of the Boston & Albany Railroad that contained carbon 0.360, phosphorus 0.124, silicon 0.469, manganese 0.571, and which had then been in the track five years. That rail is still in service and in good conditions ». (Total 7 years.)

Some of the views were opposed to the introduction of chemical composition into the specification requirements as of « no value to the engineer, for no matter what the chemical composition, it is upon the physical qualities at last that he must rely to determine whether or not it will answer his purpose ».

This period of investigation into the economies of steel rails, 1873 to 1881, was concerned for the most part with the effort to obtain a rail more resistant to wear, and thus give a longer life. The question of breakages and crushing was considered also, but the great effort seemed to be to obtain a rail which would give more service.

A. S. C. E. Committee of 1885.

These reports and monographs had an effect upon the rail design as already pointed out, but the improvement in wear was largely counteracted by the continually increasing traffic and weight of rolling stock. Mr. M. N. Forney, secretary, Master Car Builders' Association wrote a paper in 1884 saying — « the treads and flanges of wheels should be made of the same shape as the heads of the rails ». In the same year the round-cornered rail (5/8 inch radius) was made standard on the Pennsylvania Railroad instead of the 5/16 inch radius. The belief that the rail was being worn out or destroyed by excessive wheel loads through lack of sufficient bearing area was gaining with increased intensity, so that the « rail-question » was taken up once more by the American Society of Civil Engineers by the adoption of the following resolution, 25 June 1885 :

Whereas, the relation which the form of the head of a rail should bear to the section of a car-wheel tread and flange has recently been in dispute, it being asserted on the one hand, that they should have as long a line of contact as possible, and, on the other hand, that such long contact would be dangerous and injurious;

. . . .

Resolved that a committee (1) be appointed to report, « to what extent and at what points it is expedient that their sections should be such as to bring them normally in contact, and to what extent and at what points it is not expedient that they should be so in contact ».

. . . .

Causes of rail wear.

The Committee collected a large amount of information from rails and wheels worn in service, and it was issued in a preliminary (1) report which caused many members to enter into the discussion with carefully prepared statements. The causes of rail and wheel wear were presented in the following statement :

It is far from true that, as has sometimes been carelessly assumed, the only wear, or the chief wear, results from crushing, either on curves or tangents. There are these three causes for wear :

1° Direct sliding of wheel on rail, such as is generally admitted to cause substantially all the extra curve wear;

2° Molecular interlocking of the fibres, which is the cause of the wheels revolving instead of sliding, and wears and bends the fibres on their side;

3° Direct crushing and disintegration of the fibres from the effect of insistant weight.

Of these three causes your Committee are decidedly of opinion that the last is by much the least important of all, and they are led to this conclusion by the fact that it seems easy to account for as much wear as occurs by the first two alone. The wear from the first two is most certainly not inversely as the area, but comes nearer to being directly as the area (the total pressure being the same), if brake experiments and others may be trusted. Take direct sliding wear on a tangent, for example. Whenever the wheels are of different diameter direct sliding occurs. It takes a difference in diameter of less than 3/100 of an inch to cause as much slipping as on a 1 degree curve.

. . . .

This latter statement is based on M. A. Wellington's empirical formula for curve wear : « Extra wear due to curvature in pounds per yard per 10 000 000 tons duty on a d degree curve $= 0.03\ d^2$. »

Wheel and rail contact.

In considering the problem, (1) Mr. D. J. Whittemore, chief engineer, Chicago, Milwaukee & St. Paul Railway, was impressed with the fact that the trouble with rails was not *wear*, but destruction from excessive loads. In a long and carefully prepared argument he states in the opening sentence : « Present practice imposes from two to three times the weight on railway wheels that was customary a few years ago. »

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(1) The Comittee, which was appointed, was H. Stanley Goodwin, A. M. Wellington, Samuel Rea, George L. Morrisson, Thomas Rodd, S. M. Felton, Jr., James Archbald (*Transactions, American Society of Civil Engineers*, vol. XIX, 1888).

(1) *Transactions, American Society of Civil Engineers*, vol. XXI, 1889 : « Cylindrical wheels and flat topped rails for railways, by D. J. WITTEMORE, past president, A. S. C. E.

(¹) Mr. Max J. Becker in speaking on this point stated :

> The trouble is that the increase in the carrying capacity of the rail has not been kept up in the same ratio with the loads imposed. In the earlier fifties the general weight of rail was about 50 pounds per yard. At that time the freight cars carried 10 tons, the locomotives weighed 20 or 25 tons. Today we are carrying 30 tons in our cars, and our engines weigh 60 tons, which shows an increase of 300 % in the loads. At the same time, the largest rail sections in this country now rarely exceed 74 pounds, so that the increase in the sectional area of the rail would be about 50 %, while the loads have been fully trebled.

He pointed out that, as part compensation for this, the price of steel rail in 1888 was $30.00 per ton against $120.00 in 1873.

Mr. Thomas Rodd said that :

> No year has passed that I have not heard discussions as to why operating officials constantly increase loads, thereby placing upon railway structures a more severe service than that for which they have been most carefully designed. These discussions have not had the slightest effect. The loads have been increased... we know very well that an increase in freight car capacity must be followed by an increase in the hauling power and consequent weight of the engines. I take it that we have to provide for actual loadings — not for the present loads only, but for greater loads than the present; and I feel sure that any effort to reduce the loads would be futile. Engineers could not, even should they wish to do so, stand in the way of progress in railway transportation.

This view of overloading was dwelt upon by others, Mr. James B. Francis, past president, American Society of Civil Engineers, saying that :

> This question of flow is a case of exceeding the elastic strength of the metal. By this I mean a strain, so that the metal does not return after the load is lifted. The remedy would be to reduce the strain; there is no other way to accomplish it. I don't see that it depends upon the strength of the rail, but upon the strain that is applied to the upper point in the rail. If the strain there is beyond the elastic limit this flow will take place.
>
> « It is true, as reported by your Committee », said Mr. Whittemore, « that our rails fail with little material abraded from the top. The fact is, they are crushed, after flow of metal has reached its limit; they fail like all other crystalline substances when overtaxed, by rapid disintegration and not abrasion, and it is the exception to find in the scrap heap a rail with the head well worn down ».

He made use of the Grashof formula for determining constants for rollers on plane surfaces to show « that driving wheels of locomotives, as then loaded, must have a diameter of about 17-feet to keep the contact between it and the rail within the elastic limit. Calculations made since convince me that this was an under-estimate ».

« The fact is that there is hardly a wheel turning under our freight cars when loaded to their scheduled capacity, or a driver under our locomotives, that does not strain the metal in the rail beyond its modulus of resistance. From the tests given we can safely assume that for the majority of our rails this modulus can be taken at 45 000 pounds. In many instances it falls below 40 000.

(¹) *Transactions, American Society of Civil Engineers*, vol. XX, 1889.

With a modulus of 45 000 pounds the car wheel can sustain about 6 000 pounds within the elastic limit, and this approximates to the weight on passenger equipment; hence the high service show for the steel tired wheel. »

Intensity of pressure on rails.

The Committee, in the preliminary report devoted considerable space to the question of top corner radius of the head, but Mr. Whittemore's advocacy of cylindrical wheels and flat topped rails turned the weight of discussion to the intensity of stress upon the top of the rail head. It was well expressed by Mr. G. Bouscaren in these words :

> Hence, if economy of power is the first object of the engineer, no greater professional sin can be committed by him than to tax materials beyond their limit of capacity.

He believed, however, that the flowing and disintegrating of metal, and the coring and splitting of heads was primarily attributable to the bad quality of the steel, and that we should have a harder steel sufficiently rolled at the proper temperature.

He raised another important point also, the thickness of the base flanges which had been made by Mr. Welch as thin as possible and left that way ever since, in order to have as large a percentage as possible in the head. Mr. Bouscaren said :

> My experience is, that, with very few exceptions, the breaking of steel rails in the track begins at the flanges, this is an indication that the flanges should be made narrower and thicker.

To this discussion, Mr. J. B. Johnson made a very important contribution of original research. He found that Mr. Whittemore's tables of allowable wheel loads for given radii and unit stresses were based on an erroneous use of the formulæ of professor Grashof, and he undertook to prove this by laboratory tests with wheels on rails, as well as by mathematical analysis. (1) Like Ashbel Welch, he performed experiments to obtain actual areas of contact by pressing polished sections of a cast-iron car-wheel and of a locomotive steel driving-wheel upon the polished cylindrical top surface of a steel rail which was coated with wet chalk.

From these measurements it was believed :

1. *That the area of contact increases directly with the load.*

2. *That the mean intensity of pressure is a constant for all loads.*

3. *That in these experiments this mean intensity of compressive stress, for all loads, was about 82 000 pounds per square inch.*

4. Since the maximum deformation (at the centers of these areas) is twice the average deformation (assuming the volumetric deformation to be that of a segment of a paraboloid of revolution), then *the maximum compressive-stress intensity for all loads is about 164 000 pounds per square inch.*

5. Since no measurable permanent set was produced by any of these loads on either wheels or rail, it follows that *the « apparent elastic limits » of the materials had not been reached for this condition of contact, although the ordinary elastic limit of the rail material, for a free flow was about 50 000 pounds per square inch.*

Additional explanation of these important conclusions has been stated as follows:

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(1) *Transactions, American Society of Civil Engineers*, vol. XXXII, 1894 : « Friction Rollers » — Discussion of Crandall and Marston's paper in same volume, and « The Materials of Construction », by J. B. Johnson, C. E.

The law seems to be for 22-inch radius steel tire, on 14-inch radius steel rail,

$$A = 0.000012\,P \quad . \quad . \quad . \quad (9)$$

where A is area of contact in square inches, and P is the load on wheel in pounds. What the maximum stress is cannot now be stated, but if the mean stress is about a constant for all loads, it is probable that the maximum stress is nearly a constant also.

Furthermore this maximum stress must be nearly twice the mean stress, since the maximum distortion must, of necessity (a geometrical necessity), be twice the mean distortion.

We may, therefore, say that the maximum stress is nearly

$$K = \frac{2\,P}{A} \quad . \quad . \quad . \quad . \quad (10)$$

and from (9) we obtain for a 44-inch steel driver on a 14-inch radius steel rail.

$$K = \frac{2\,P}{A} = \frac{2\,P}{0.000012\,P} = 167\,000$$

pounds per square inch.

This astonishing result seems at first incredible, but it cannot, in the writer's opinion, be successfully disputed.

. . . .

This result leads at once to the study of the elastic limit in compression. Here is where we have all been blundering. There is no such thing as an unconditioned elastic limit in compression as there is in tension.

The elastic limit is the point where the material begins to permanently distort or flow, or where the particles begin to rearrange themselves in new positions.

Now, for compressive stresses, we have various conditions limiting the flow of the particles. For instance, a cylindrical column in compression is in a condition of free flow. There is nothing to hinder the lateral spreading action of the column as it shortens up. If we place a square-ended die on a flat surface and load it until it begins to indent that surface the material below the end of the die must flow laterally around the corners of the die to get out of the way. But this lateral flow is restricted by the surrounding metal. Here we have a restricted flow, and a much higher pressure is required before it will occur.

But when a sphere or cylinder is placed on a plane, or one cylinder on another cylinder, and loaded, the maximum stress and the greatest tendency to flow is at the center of the area of contact, and here the flow must begin, but this metal cannot find as near escape as in the case of the square-ended die, for the pressure diminishes gradually, and the flow must be through a longer distance before it can really escape. Here, therefore, is a case of still greater restriction of flow and still higher elastic limit.

I estimate that a grade of steel having an elastic limit in compression when tested as a column, with free flow of some 40 000 to 45 000 pounds per square inch, has a limit of about 100 000 pounds under a square-ended die, and of some 160 000 to 200 000 pounds under curved surfaces of as much as 20 inches radius.

. . . .

When two cylinders are in contact, their axes being at right angles, the volumetric distortion for each of the surfaces is fairly represented by the segment of a paraboloid. A property of the segment of a paraboloid is that the maximum ordinate is twice the mean ordinate, or, in other words, the volume of the segment is one-half the enclosing cylinder. This fact authorizes the statement made above, that the maximum distortion at the centers of these areas of contact is twice the average distortion, and hence the maximum stress is twice the average intensity of stress as above stated.

. . . .

The conclusion which I am coming to is, therefore, that the maximum stress in and also the elastic limit of steel rails under wheel loads is dependent on the radii of the wheel and the rail, and that the maximum stress is practically independent of the total load on the wheel. Also that the elastic limit is in the vicinity of 200 000 pounds per square inch for the ordinary locomotive drivers on the ordinary steel rails.

These conclusions are so contrary to the commonly received opinion on this subject that the writer hopes that by the time his forthcoming paper on this subject appears will have made similar experiments, and can thus either fortify his conclusions or prove them erroneous.

When a wheel tread becomes worn or grooved, and the rail head becomes flattened somewhat, so that the surface of contact is extended laterally across the rail from 1 to 2 inches, the effect on the intensity of the stress is the same as though we had a flat wheel on a flat rail.

It is sometimes said that if a flat topped rail is the surface of least wear the rail would constantly approximate to this form. This is not true. If the rail is originally curved, and the wheel tread flat or conical, the final section of both will be a mean between the two original surfaces. And this is exactly what happens. The tread becomes grooved, and the rail becomes flattened, both approximating to a mean between the original curvature of the rail head and the flat tread. When they have both come to the same curvature, the effect is exactly the same as a flat tread on a flat rail.

If, now, both wheel tread and rail top should be made flat in the start, I see no reason why they should not remain so, except from the rounding off of the corners somewhat as a result of the grooved drivers shifting slightly in a lateral direction. If, when the rail is first laid, it cants slightly, it will soon adjust itself by cutting into the tie more on one side than on the other, from the increased pressure on the high side.

If a flat head cannot be rolled, then let the head be as flat as can be rolled, for certainly a wider surface of contact is of the first importance.

The study of the (1) Intensity of Pressure on Rails was taken up once more by a committee of the American Railway Engineering Association by means of laboratory and service research :

1. By an exploration of the interior of the head of the rail through holes, diagonal upward from the bottom towards the centre of the head, and also at increasing depths from the top through the side of the head parallel with the base, after subjecting it to definite repetitions of rolling load.

2. To define, so far as possible, the area of contact between the rail and the wheel at different periods throughout the test, both in the laboratory and in the track.

3. To determine the hardening effect of the rolling load on the contact and adjacent surfaces.

4. To determine the distribution of the intensity of pressure within the area of contact.

The distortion of the holes drilled in the head was measured by tapered, turned and ground steel plugs.

In the field, the areas and rolling contacts under drivers and wheels on the rails were taken on copper sheets of about 0.0015 inch in thickness.

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(1) *Proceedings, American Railway Engineering Association*, vol. 19, 1918.

The committee stated that :

for the present, the only conclusions that can be drawn from the tests which have been made are but indications.

Field Tests.

1. That for this section and composition of rail, initial loads of 30 000 pounds or more per wheel of cast iron and chilled tread, of 33 inches in diameter, were too great for its transverse holes, and produced flow or closure at least 3/8 inch below the bearing surface.

2. The loads of 25 000 pounds produced but slight flow or closure in the three uppermost transverse holes, and this extending not more than 1/4 inch in depth.

3. That preliminary light loads, by cold-rolling the surface, may adapt the material to subsequent heavier loads.

Laboratory Tests.

4. The diagrams of the plotted tables show that the stresses in the metals are locally less severe than we had expected to find in the surfaces of the pressure zone contacts of the wheel tread and the rail head.

5. It is important, as the theory and evidence show, that the metal of the circumjaçent layer of each pressure zone of contact for the wheel tread, also that of the rail head, is in position not only to utilize the elasticity of the metal to help carry a given load but to increase an area within the elastic limits of the metals nearly in proportion to the loads applied.

6. The action of the rolling wheels on the rail heads is a gradually applied load from zero to the maximum, then reducing again to zero, both for a unit length in the wheel tread or rail head, and is not a suddenly applied load, even for a mile-a-minute or faster trains.

7. The *round* type of area of contact shows the greatest average unit intensity of pressure.

8. The *longitudinal oval,* or the *transverse oval* type indicates the lowest average unit intensity of pressure.

9. The *longitudinal elliptical* or *transverse elliptical,* in which the major axis is two or more times the width of the minor axis, indicates also a favorable average unit of intensity of pressure.

10. The *transverse oval* or *elliptical* under steel or cast-iron wheels is more favorable for the rail heads than the *round.*

11. The reciprocal relations of the loads carried on the metal of the wheel treads to the metal of the rail heads should be studied from the voluminous service tests now available.

In this connection, the work of the (¹) Joint Committee on Stresses in Railroad Track of the American Railway Engineering Association and the American Society of Civil Engineers has a very important bearing. The field work embraces many thousands of measurements, requiring prolonged intensity of study and compilation, both of which were performed by professors and students of the University of Illinois under the direction of professor A. N. Talbot.

In order to give some idea of the high stresses which may be caused at the present time by certain heavy locomotives at speed, the reporter has deduced the following notes from the data of the report :

1. The stress in rail of 85-pound section under a freight locomotive (class I-1-s), or 2-10-0 type, with 67 000 to 72 600 pounds on a driving axle, will be from 33 000 to 39 600 pounds per square inch at the speed of 40 miles per hour on tangent track.

(¹) *Proceedings American Railway Engineering*, vols. 19, 1918; 21, 1920; 24, 1923. — Transactions American Society Civil Engineers, vols. LXXXII, 1918; LXXXIII, 1919-20; LXXXVI, 1923.

2. The stress in rail of 85-pound section under a passenger locomotive (class M-1), or 4-8-2 (Mountain) type, with 68 500 to 69 500 pounds on a driving axle, will be from 27 000 to 31 000 pounds per square inch at a speed of 60 miles per hour on tangent track.

3. On a 6° curve, the effect of speed and counter-weight may double the stresses for straight track approximately, and, therefore, the stress per square inch in 85-pound rail under the I-1-s locomotive may be expected to vary from 66 000 to 80 000 pounds per square inch at a speed of about 40 miles per hour.

Similarly, the stress per square inch in 85-pound rail under the class M-1 may be expected to vary from 54 000 to 62 000 pounds per square inch at a speed of about 50 miles per hour.

4. The analysis of stresses under static loads for these two locomotives shows that the stresses at speed on curves might be very high on 85-pound rail, and also that for 130-pound rail the stresses per square inch are only about 1/2 of those for 85-pound rail.

Even with the heavier rolling-stock of the present day, these stresses do not amount to more than one-half of the 164 000 pounds per square inch maximum compressive stress intensity, *under the condition of restricted flow*, for all loads of professor J. B. Johnson, previously quoted, which he found rail steel able to stand.

Nevertheless, it is well known that the heavy rolling-stock of the present day breaks down the surface structure of Open-hearth steel rail and causes the metal to flow.

Principle dimensions for rails.

After careful consideration of the arguments submitted in discussion of the preliminary report, the Committee of 1885 submitted its conclusions in 1889 :

First : A twelve-inch top radius as a standard for rail sections of all weights.

The prevailing sentiment, which your Committee shares, appears to be that the end sought in the suggestion of an entirely flat top between the rounded corners, *viz.*, a wider bearing for the wheel-tread, is a desirable one, but that it is and will be better secured in practice by using a slight curve for the top of the section instead of a straigth line.

The evidence is that an entirely flat top is difficult, if not impossible, to roll properly; trials have resulted badly. Inevitable irregularities of track and the usual slight bends in the web, due to the rails lying on their sides when hot, would throw the bearing of the wheel-tread on one or the other corner instead of evenly across the top, causing early flowage and rounding of the section. The standard wheel-tread is now slightly coned, a perfectly cylindrical tread having been first rejected. While a few hold that the coning has a sensible influence on curve resistance, the belief is general that coning does have a sensible steadying effect to diminish oscillation, and it is questionable if it would be wise to wholly dispense with it. Were the tread originally perfectly cylindrical, with an even bearing for the whole width of the rail head, the necessary gauge play alone would tend to wear it hollow. Under existing conditions, wheel-treads wear slightly hollow, corresponding to about a 12-inch radius, very early in their lives. As a consequence, nearly all rails now wear down to a curved top on the outside as well as the inside of the head. Were flat rails and cylindrical wheels universal on any one line, and were they thus made free from all tendency to wear to a curve, the constant interchange of cars would bring hollow treads on flat rails and straight treads on round-top rails. With top curve, the load is sustained centrally and transmitted directly downward through the web. Without it, one or the other corner will sustain the load in practice, and neither long in succession, causing a tendency to split off the side of the head if the metal be in any way defective. Most wheels being worn slightly hollow, the bearing is in practice now tolerably wide.

For these and other reasons your Committee is entirely clear that the attempt to introduce a perfectly flat top is inexpedient.

(The original tee-rail section of Robert L. Stevens in 1830 had a flat top. — Reporter).

Second : Your Committee recommends a broad head relatively to depth for sections of all weights, taking care not to go too far in either dimension, especially in very large or very small sections, or to endanger the flange cutting into the joint.

Your Committee is much impressed with the weight of evidence and opinion tending to show that, in the effort to secure three ends in themselves desirable and proper, too little attention has been paid to metallurgical laws and processes of manufacture in designing rail sections. The tendency has been strong :

A. — To secure a broad bearing on the tie by widening the base. At the same time;

B. — To save metal by making the base thinner, and also the web; while :

C. — To increase tonnage life, additional metal has been placed on top of the rail head.

These ends, as stated, are in themselves good, but the result of seeking to obtain them in this way is a great disproportion of mass in the different parts of the section; and this in turn requires that, in order to have the thinner portions of the section sufficiently plastic for the finishing passes through the rolls, the head must be so hot when it leaves the rolls as to be almost semi-fluid; and so the rolls do little of that effective compressive work which unquestionably is essential for properly consolidating and toughening either wrought iron or steel. This unequal temperature, after leaving the rolls, also makes it much more difficult to insure that the rails shall be straight when cool and, hence, results in more *gagging*. As there exists also a constant and injurious tendency to roll even the thinner parts tolerably hot, in order to quicken the process, saving making seconds, and reduce the number of passes, it will be seen how probable it is that the heads of many rails have been leaving the rolls in but little better molecular condition than when they entered them.

. . . .

The Committee also calls attention to the better balance of the European « bull-head » sections favoring better rolling conditions, and that also in the case of flat-base American sections where used the tendency is to use thicker bases and webs. The correlated Committee of 1890 decided upon the relative proportions of 42 % of the metal for the head, 21 % for the web, and 37 % for the flange.

Third : Your Committee recommends a one-fourth (1/4) inch corner radius, as a standard for sections of all weights. (Changed to 5/16 inch by the correlated Committee of 1890 on Standard Rail Sections. — Reporter).

. . . .

Fourth : Your Committee recommends a one-sixteenth (1/16) inch lower corner radius for the head, as a standard for sections of all weights.

. . . .

Fifth : Your Committee recommends that, starting from a sufficient base width of head to give ample bearing for the joints, or to conform to recommendation

No. 1, the sides be carried up vertical, as a standard for sections of all weights.

. . . .

Sixth : Your Committee announces as final conclusions the preliminary conclusions as to the general laws of rail and wheel wear included in its Preliminary Report.

A. S. C. E. rail sections.

After hearing the report of this Committee, it was evident that the real result had not been reached, although it had complied fully with the commission given to it, the analysis of the proper relation to each other of the sections of railway wheels and rails; and so in 1890 a (¹) new committee composed in part of the previous committee membership was named to design *Standard Rail Sections*. Each member of the Committee submitted a complete series of designs for rail sections varying by 10 pounds difference in weight from 40 pounds to 100 pounds per yard, both inclusive, and these were submitted as a preliminary report in 1891 for membership consideration. In the meantime, there was not much more discussion of the subject, their bolts having been shot at the members of the preceding committee. The final report was made (*Transactions American Society of Civil Engineers*, vol. XXVIII) in 1893, quite brief in text, but it contained the A. S. C. E. rail designs which were subsequently used by many of the railroad companies very extensively. These designs varied in weight by 5 pounds per yard from a 40-pound section to one of 100 pounds per yard.

The ratio of base to height remained at 1.00, and the edges of the base were still thin according to the principle established by Ashbel Welch; and this, too, in spite of the fact that the Committee recognized the importance of thicker and narrower base.

Rail Committee, A. R. E. A., 1899.

The rails of Bessemer steel continued to give unsatisfactory results from breakage and crushed and split heads, and one of the most numerous types of breakage was the half-moon fracture in the base. Failures continued to increase with the increased traffic and weights of rolling-stock, so that, by the end of the century, concentrated study was put upon the problem again.

The American Railway Engineering Association having been organized in 1899 with standing committees to study the economical maintenance of railways, the Rail Committee in its first report (1900), « being of the opinion that the A. S. C. E. sections are a step in advance, thinks that no new sections should be suggested until we have had full time to learn from experience the merits of these sections. It is recommended that all members of this Association, whose lines are not using these sections, be urged to have them adopted and used on their lines ». About that time 75 % of all the rails rolled by American mills were of these sections.

It was announced that the Committee would prepare standard specifications for general adoption. This was the beginning of co-ordinated work upon steel rail specifications, and it has continued to the present day. President Wallace said : « Of course, we realize that we don't expect to exhaust the subject at this meeting or the next or in our life-

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(¹) Final membership of 1890 Committee: G. Bouscaren, J. Foster Crowell, S. M. Felton, Jr., J. D. Hawks, R. W. Hunt, Virgil G. Bogue, E. D. T. Meyers, Samuel Rea, F. M. Wilder, Thomas Rodd, A. M. Wellington.

time, but we are simply laying the foundation now for our future work ».

Heretofore, since 1873, the principal co-ordinated study had been given to rail sections, culminating in the recommendations of the A. S. C. E. sections in 1893. The study of specifications had been made by the railroad companies separately, but now it was able to be undertaken by a standing committee. R. W. Hunt said: « I think, in the case of the buyer of steel rails, he should have the right to say what he wants, pay what they are worth, or else leave the details of their making alone and cease complaining. »

(¹) The first uniform specifications for steel rails were submitted by the Committee at the Convention of 1902, and were adopted. The work of revision has continued up to the present time.

Rail Committee, A. S. C. E., 1902.

In the same year, another committee was appointed by the American Society of Civil Engineers to study Rail Sections, and after preparing preliminary specifications in 1907 (not adopted), remained in existence until 1910, when it was discharged, having yielded to the American Railway Engineering Association as the leader in this subject.

Rail Committee, A. R. A., 1907.

As the record of rail failures was getting worse, and as the facts were being pressed upon the executive officers of the several railways, the subject was taken up finally, in order to be under concerted effort, by the official organization of the executive and operating officers of the railways, the American Railway Association, and (¹) a committee was appointed for the purpose early in 1907 to examine exhaustively into the subject of rail design and specifications, the manufacturers of steel rails being invited to co-operate.

Rail Committee, P. R. R., 1907.

At the same period, the Pennsylvania Railroad System, while continuing as an interested worker with all these associations, appointed a committee 4 June 1907, of its own officers and two rail manufacturers to revise its rail designs and specifications.

Heavy base, balanced rail sections.

The specifications in use were those of 1 october 1901, which superseded those of 1 April 1885, with the carbon modification of 1889; and A. S. C. E. rail sections were being used on one portion of the System, while P. R. R. sections were standard within the rest. Both of these designs had the thin ends of the base which have already been pointed out as failing by fracture. It was strongly maintained by the manufacturers that the metal was not rightly proportioned between head, web and base, and that the thin base cooled too quickly in advance of the heavy head to avoid thermal conditions which helped to make the base a weak point. This Committee, therefore, designed the *first heavy base sections*, which were issued 20 September 1907, the 85-pound P. S., and the 100-pound P. S. rail sections of the Pennsylvania Railroad System.

(¹) *Proceedings American Railway Engineering Association*, vol. 3, 1902. Members of Committee: R. Trimble, J. T. Richards, Thos. Purcell, A. W. Johnston, C. E. Wickham, R. W. Hunt, G. B. Woodworth, F. E. Abbott, W. R. Webster, W. T. Manning, H. Pierce.

(¹) G. L. Peck, J. T. Richards, F. A. Delano, R. Montfort, William Garstang, R. E. Ettenger, W. E. Fowler, P. H. Dudley, J. W. Kendrick.

Open-hearth steel.

Rails of Open-hearth steel had been experimented with already, as the belief was gaining ground that Bessemer steel no longer provided a sufficiently strong or hard rail to carry the rapidly increasing traffic and rolling-stock axle-loads, and the revised specifications, superseding those of 1 October 1901, and providing clauses governing Open-hearth steel, were adopted 4 February 1908. Many changes have been introduced since that date, and the passing of Bessemer steel for rails occurred between this date and the year 1913, except for minor and exceptional uses.

R. A.-A and R. A.-B rail designs.

The Committee of the American Railway Association submitted its final report 23 March 1908, accompanied by Specifications for Bessemer Steel Rails, Specifications for Open-hearth Steel Rails, and Rail Sections, type A and type B, which were adopted, having been first submitted tentatively 1 October 1907.

This Committee was the first to develop the « nick-and-break » test at the suggestion of Mr. William Metcalf, and it was introduced into these and also the Pennsylvania Railroad System specifications.

« If the test piece does not break under the drop test, it shall then be tested to destruction, and, if when so tested to destruction, the test piece shows pipe or physical defect, the top rail from each ingot shall be rejected », and so on, proceeding with the next lower rail in the same way.

The rail sections varied by 10-pound increments from 60 to 100 pounds per yard, in two types, designated as R. A.-A and R. A.-B.

There has always been two groups of thought in rail design in the United States, those on the one hand adhering to the type established by Ashbel Welch, with size of head predominating over height of rail which gave strength and stiffness, although at the same time believing in as wide a head as possible with those restrictions, and, on the other hand, those advocating a thinner head and higher rail in order to make stiffness and strength predominate. Both types were, therefore, required in order to have agreement. The top radius of the head and the fishing-angle were different in the two designs.

However, the Committee retired from the field with this report, and delegated the continuance of the work to the American Railway Engineering Association in the final paragraph as follows :

> Your Committte respectfully recommends that the series of sections of types « A » and « B » and the specifications for Bessemer and Open-hearth steel rails, submitted with this report, be adopted as the recommended practice of the Association, and that the sections and specifications be referred to the American Railway Engineering Association with the request that they follow up the question of determining the details as to drop test, etc., by observing the actual results of rails rolled under the new sections, and that they also arrange to collect from the different members and tabulate all information as to comparative wear of rails rolled from the different parts of the ingot, and all other information necessary to a proper study of the problem. That they be further requested to keep careful record of the comparative results in service of rails of types « A » and « B » and to prepare and submit to this Association a single type of section which will embody their ideas as to the best type that can be designed for use as a single standard to be adopted by the

Association, giving due weight to every factor entering into the problem.

The American Railway Engineering Association thus became the successor of all these committees, though there is another committee at work upon the problem of specifications, that of the American Society for Testing Materials, consisting of manufacturers and consumers.

R. E. rail designs.

After long study, a series of rail sections, designated by the mark « R. E. », varying in weight by 10 pounds per yard, was adopted by the American Railway Engineering Association, as follows :

R. A.-A. . .	90 pounds.	Adopted 1915, vol. 16,
R. E.	100 —	
R. E.	110 —	
R. E.	120 —	
R. E.	130 pounds.	Adopted 1920, vol. 21,
R. E.	140 —	
R. E.	150 pounds.	Adopted 1924, vol. 25,

and afterwards by the American Railway Association, except the last.

Rollings have been made of the 90, 100, 110 and 130-pound, but not of the others.

Chemical constituents.

The constituents of carbon steel rails, called « Alloys » in the questionnaire, are ascertained by the chemists of the manufacturer at the mill, while the rails are being rolled, and are checked from time to time by the chemists of the railroad companies. The amount of each element allowed in the tentative specifications for experimental lots of dead setting Open-hearth carbon steel rails of the American Railway Association is :

—	Weights in pounds per yard :		
	70 to 84.	85 to 110.	111 and over.
Carbon.	0.53 to 0.68	0.62 to 0.75	0.67 to 0.80
Phosphorus, not to exceed.	0.04	0.04	0.04
Manganese.	0.60 to 0.90	0.60 to 0.90	(1) 0.60 to 0.90 (1) 0.50 to 0.80
Silicon, minimum	0.20	0.20	0.20
(1) Optional.			

Piping.

It is considered that effervescing steel during teeming of the ingots conduces to segregation, and, therefore, brittleness. If it can be made to set quietly in the molds, it is believed that the steel will become more ductile and less segregated, and in order to accomplish this a larger amount of the de-oxidizer, silicon, than usual has been provided for in the tentative specifications above quoted. It is considered likely that the higher silicon may induce a deeper pipe, but those favoring the specification do not consider the pipe as harmful as the segregation, because the steel will be more ductile. The question of pipe has, therefore, been ignored.

In accordance with the recommendation of the Committee, more than 40 000 tons of rail complying with these specifications have been rolled for ten railroads, and placed in the track for service record. The effects of the drop tests (falling weight), at the mills have been carefully studied with the following results :

1° With carbon from 0.62 to 0.75 %, the average exhausted ductility has ranged from 14 to 24 %;

2° With carbon from 0.72 to 0.86 %, the average exhausted ductility has raned from 7 to 12 %;

3° The segregation for melts with silicon over 0.20 % shows only one-half the percentage for melts with silicon under 0.20 %.

Some of the melts contained silicon up to 0.33 %.

Segregation.

The question of segregation is of great importance, and has been discussed previously by the reporter (1). Segregation is an almost invariable accompaniment of the defective head and web, and has nearly always as its associates one or both of the other defects, brittleness and hardness. Sometimes slag is present, and sometimes foreign steel due to the cutting or protection of the ingot-mould stool. The results of the examination of many « Split-head » rails seem to show that they are nearly always segregated rails having hard, unsound metal in the interior and softer metal at the surface. The flow of the softer metal develops a split in the harder unsound and less ductile metal in the interior of a badly segregated rail resulting in a split head. In addition to the quiet setting, high silicon plan of the American Railway Engineering Association for reducing segregation, the use of a sink-head in casting ingots, as advocated by (1) Sir Robert Hadfield, should help in the reduction of segregation and produce a denser and tougher steel by making sounder and more homogeneous ingots. It is noticeable in examining the tabulations that scarcely any of the failures occurred in the joints, showing that the condition of the road-bed was not the important factor in defective heads.

The segregated rail which flies into many pieces suddenly under a train is the most dangerous failure with which we have to deal. A rail of this character is shown in figures 7 and 8. It is highly segregated, 21.43 %, has in addition a very large pipe, and is very hard, 270 Brinell. These defects are so bad that it is not known what effect the high silicon may have had.

A fair measure of segregation may be expressed by the specification quoted below under « Analyses ». In the case where this was used, the railroad company fitted up a car with the chemical apparatus required and a force of chemists who made the analyses at the mill while the rail was being rolled. It was necessary to pay an extra charge to the manufacturer for this privilege.

Analyses.

In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows :

(*a*) For Bessemer process, the manufacturer shall furnish to the inspector, daily, carbon determination for each melt before the rails are shipped, and two chemical analyses every twenty-four hours, representing the average of the elements, carbon, manganese, silicon, phosphorus and sulphur, contained in the steel, one for each day and night turn, respectively. The analyses shall be made on drillings taken from the ladle test ingot not less than 1/8 inch beneath the surface.

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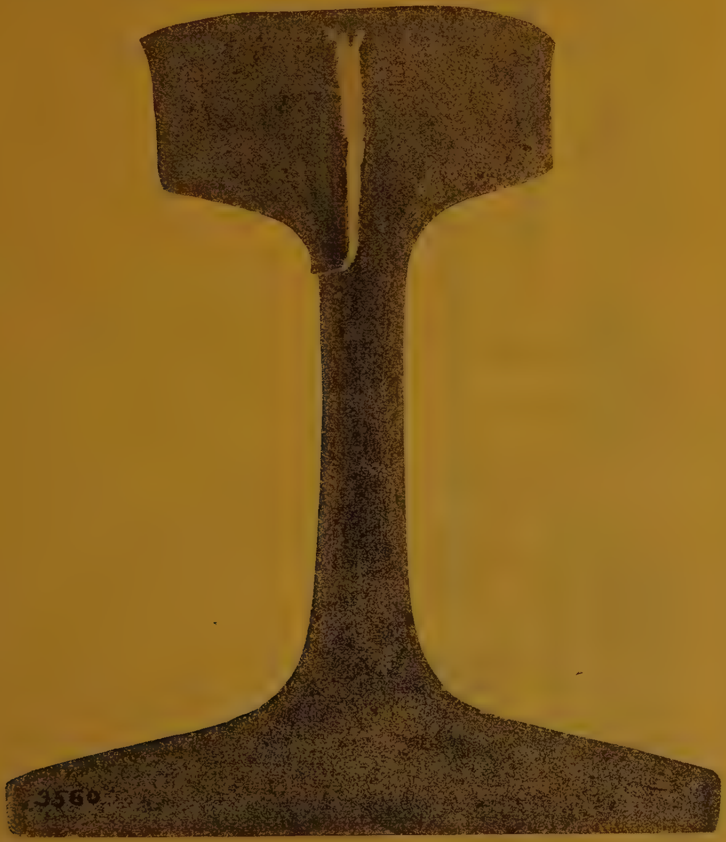
(1) *Minutes of the Proceedings. The Institution of C vil Engineers*, vol. CCI, 1915-16. — *Proceedings American Railway Engineers Association*, vol. 17. 1916 : « *Some of the Causes of rail failures* ».

(1) *Proceedings, American Railway Engineers Association*, vol. 14, 1913.



130 lb. P. S. Laid : 8-1921. Removed : 11-30-23.
In service 2 years, 3 months in tangent track in Gould Tunnel.

	Open-hearth						
Borings.	C.	Mn.	P.	Si.	S.	Average Brinell hardness.	Position
Head « O ». . .	0.840	0.83	0.039	0.249	0.051	260	in ingot « A ».
Web « M ». . .	1.02	0.84	0.047	0.249	0.063	272	

Fig. 7.

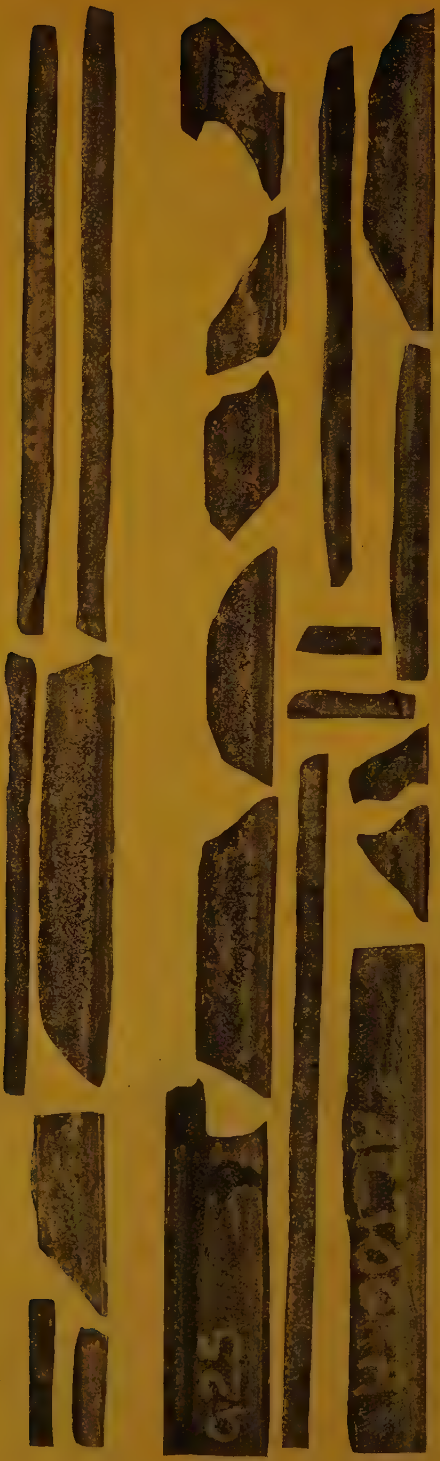


Fig. 8. — Appearance of portion of broken rail.

(*b*) For Open-hearth process, the makers shall furnish the inspectors with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each melt.

(*c*) For Open-hearth process, a check analysis will be made by the purchaser of a piece of rail representing a melt, after the rails from that melt have passed the physical requirements. On the request of the inspector, and in his presence, the manufacturer shall furnish from one of the drop-test pieces representing the melt, drillings satisfactory to the inspector, taken with a 5/8 inch flat drill, parallel to the axis of the rail, at a point one-third of the distance from the upper corner to the center of the head, as shown at location « O » in figure 9. The analysis from these drillings shall conform to the chemical requirements specified and failure to meet these requirements shall be sufficient cause for the rejection of the entire melt.

(*d*) For Open-hearth process, after the rail has passed the physical requirements, additional drillings will be taken from the same rail, and in the same manner as specified in (*c*), at the junction of the head and web, as shown in location « M », figure 9. The carbon determination from these drillings shall be within 12 % of the amount found at location « O », figure 9. If the test from the top rail fails to meet this requirement, all the top rails from the melt shall be rejected, and a similar determination shall be made from location « M » of a second rail. If this test fails, all the second rails from the melt shall be rejected, and a similar determination shall be made from location « M » of a third rail. If this test fails, all the remaining rails from the melt shall be rejected.

(*e*) If, however, the segregation found at location « M » in any rail in a rolling exceeds 25 %, when determined as provided for in (*d*), the progressive testing of the second and third rails will not be permitted on any subsequent melts; but on such melts the failure of the top rail to pass the requirements provided for in (*d*) will cause the rejection of the entire heat.

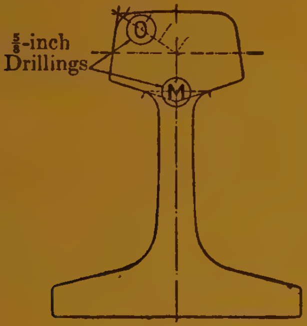


Fig. 9.

In speaking of segregation now, reference is made usually to the difference between these « O » and « M » determinations of the percentage of carbon. 12 % was fixed arbitrarily as a reasonable amount for causing rejection of the rails examined. It is an excellent chemical method of rail survey, as it gauges rejection progressively in accordance with the defects detected, because the products of different mills may vary greatly in their quality. It is much more useful and satisfactory than an arbitrary percentage of discard. It brought about rejection to as much as 40 % in some cases, but usually it amounted to 18 or 20 %.

Broken rails.

In our classification of rail failures, Exhibit 2, we have placed « Broken Rail » at the head of the list, and this together with the « Split Head » already discussed, is the most serious failure. The « Broken Rail » classification has been separated into two sub-classes, the « Transverse fissures », a crosswise break starting from a centre inside the head of the rail from which the defect spreads outward showing when fractured a smooth, bright or dark oval spot in the head; and the « Ordinary Break » covering all partial or complete fractures (square or angular breaks) in rails in which there is no Transverse or Horizontal Fissure, and in which none of the defects or damage described as «Flowed Head », Crushed Head », « Split Head », « Split Web », « Broken Base », or « Damaged » are visible. (Exhibit 2.)

In studying a group of 286 « broken rails », it was observed that 71 % of the breakages occurred when the road-bed was frozen. Further, 96, or one-third, of the fractures occurred within the limits of the joint. If there were no fault to be found with the material, this would be a clear indication that the margin of safety of the rail under ordinary service conditions was quite small; because, when the conditions became unusually severe, as in the case of a long-frozen road-bed, the rails immediately began to break, and, to a considerable extent, at the weakest point, namely, the joint. Examination in detail, however, disclosed many defects in the chemical composition and in the strength and ductility of the material, which must have had a detrimental influence and helped in a large measure to bring about failure, when the very small percentage of breakages in the total number of rails in service is borne in mind.

For instance, the material in a very large proportion of the rails is hard, a property which is usually accompanied by brittleness or segregation more or less accentuated, or both, and in that condition the material is especially subject to fracture when the road-bed is frozen. There were but thirty-one cases in which hardness was not accompanied by brittleness, segregation, or some other defect such as rolling-seam, slag, or the presence of foreign metal, due to the cutting of the ingot-mould stool, or to pieces of steel thrown on the stool to prevent cutting.

Some of the thirty-one fractures of rails exhibiting only hardness of material without other defects were probably helped by rather inferior alignment and surface of the track and poor condition of the sleeper; but such conditions of the permanent way will always be met with, as perfection of road-bed and rolling-stock cannot be continuously maintained; consequently the rail-material is expected to be strong enough to meet the conditions imposed. In only twelve cases of breakages in the joint is the additional weakness at that point not accounted for by defective material.

In twenty-one of the rails slag was present. As nineteen of these were of the heavy-base section introduced in 1908, it would appear that the methods used by the mills for pouring ingots are not as good as those formerly used, or else there is more carelessness on the part of the workmen.

Transverse fissure breaks.

The attention of railway engineers was first called to the type of fracture, named by him «Transverse Fissure», by Mr. James E. Howard, engineer physicist of the Interstate Commerce Commission, in his report dealing with the serious accident which occurred at Manchester, N. Y., on the Lehigh Valley Railroad, 25 August 1911.

Since that time, Mr. Howard has made additional analyses of this defect culminating 23 April 1923, in his Report on the Formation of Transverse Fissures in Steel Rails and their Prevalence on Certain Railroads to the Interstate Commerce Commission, a summary of which follows :

1° Girder strength;

2° Abrasive resistance from the action of wheels;

3° Cold rolling effect of wheels on the head of the rail.

Mr. Howard considers these three the features which constitute the rail problem, and if number three were eliminated there would be no rail problem.

Girder strength can be attained by increasing the section modulus of the rail, but rails do not fail from that cause. Bending stresses in the track and from gagging when straightening rail are as a rule within safe limits, and, therefore, are not responsible for the introduction of internal strains of high degree. Moderate overstraining affects only the fibres which are most remote from the neutral axis, the larger part of the cross-section not being overloaded, hence the internal strains of cooling and gagging need not cause any anxiety. In his forty years of examination of steel in all conditions he has not seen a fracture of rail occurring in service which admitted of being attributed to the operation of gagging. The number of gagging blows required to produce a fatigue fracture is so great that any anxiety concerning a few blows required in the cold straightening of rails for service should be dispelled.

The use of hard steels increases abrasive resistance, but the higher carbon rails display a sensitiveness or tendency toward the formation of interior cracks, and those cracks are held to be detrimental, and, therefore, against the use of such hard steel. It promotes a formation of transverse fissure.

Since it seems to be admitted that a relation exists between rails of high carbon content and the formation of transverse fissure, the employment of wheel loads which requires the use of hard steels necessarily carries with it a degree of responsibility in their formation.

Special steels have been tried to produce this resistance to abrasion, such as nickel, nickel and chromium together, and especially high manganese, but all are subject to internal overstraining which causes rupture. The toughness of the metal is destroyed by the cold rolling action of the wheels, the same as in carbon steel. A thin layer of metal next to the running surface of the head of the rail is embrittled by the action of the wheels. Transverse fissures have not been displayed by manganese steel rails, as the origin of its defects are in the exterior and not the interior of the head.

The third feature is the vital one and admits of solution in one way — by proper regulation of wheel loads. The effects of wheel pressures as they are received by the zone of metal at the top of the head constitutes the essence of the rail problem. It is per se the rail problem.

Internal strains of great magnitude are introduced by the cold rolling action of the wheels, and not uncommonly exceed the direct track stresses. These strains of compression are in the top of the head and reach or exceed 20 000 pounds per square inch. They are counterbalanced by tensile strains in the interior of the head, and it is in this core of tensile metal that the nucleii of transverse fissures are located. The shallow zone of metal in the top of the head is affected by the impinging pressure between the treads of the wheels and the running surface of the rails, and constitute the most critical strains to which rails are exposed producing transverse fissures.

The strains of tension and compression maintain a state of equilibrium, and change back and forth as the cold rolling action goes on, which explains the formation of two fissures in close proximity.

It cannot be urged too strongly that the rail problem centers upon the conditions which effect the shallow zone of metal at the top of the head. The rail problem is controlled by the ability of the steel to endure concentrated loads.

In general summation, known examples of transverse fissures in 1911 were few. They are now numbered by tens of thousands. They are prevalent in the main trunk lines of the country and appear sparingly on roads of lesser traffic. They are found in the product of each rail mill of the country, and appear in both Bessemer and Open-hearth rails. Thousands of heats of steel are represented. Transverse fissures are displayed where the heaviest rails are now in use. They occur in rails which were laid on bridges as well as in those laid in ballasted track.

They have been reported in rails only one month old and also in those which were thirty years old. The average age of rails which have displayed transverse fissures on different railroads show a relation to the volume of traffic on those roads.

They occur chiefly in the tracks which carry the heaviest traffic, showing the influence of loaded freight cars, since the locomotives pass over both the heavy and light tracks. On curves, transverse fissures predominate in the low rails. In the cross-section of the head they are located chiefly on the gauge side. They occur in different parts of the length of the rail.

Transverse fissures have been experimentally produced and located at will centrally over the web, in the right or in the left side of the head, according to the manner in which the rails were loaded.

In rails with shattered heads, incipient fissures have been found located in the sound metal beyond the shattered zone.

With this general exhibit of the prevalence of transverse fissures the query arises, what is to be the outcome of it? Is there any remedy against the formation of transverse fissures? The quesiton does not admit of an affirmative reply. The results of this compilation do not hold out or promise that transverse fissures can be eliminated under these conditions of service which have now been reached.

Internal strains must be reckoned with. They are just as real as those caused by the presence of external forces. There is no recourse against their introduction. The fundamental feature of land transportation, carrying loads on wheels, involves their introduction. They were present in puddled-iron rails used under light wheel loads where, indeed, the highest internal strains yet measured have been found.

It is questionable whether increased weight of rail, far beyond the heaviest now being rolled, would overcome their destructive effects.

The ideal manner of advancing this subject would be through the co-operation of the trunk-line railroads and the steel mills. Knowledge upon manufacturing features are in the possession of one party. How the material behaves is known to the other party. Each is in position to note the effects of modification in the fabrication or in the use of the rails. Each is now familiar with his own side of the case. A more logical method of procedure could hardly be suggested than the inauguration of joint efforts of those who are already most familiar with the subject matter. Laboratory facilities and their personnel adequate and competent to proceed with such an investigation are at hand in the present equipment of the steel mills and railroads.

Such co-operative efforts should be the means of expeditiously bringing vital features to the front, and reach practical ends. There is a deeper question involved than would properly come under the consideration of this joint body. It pertains to the fundamental question of what constitutes internal strains. This is a question for physicists and mathematicians to deal with, aided by metallographists.

Mr. Howard's presentation of the problem, of which the above is as brief a summary as possible, is one of the most complete, and probably the most complete that has ever been made, and with many of his views the Reporter finds himself in accord. There is but one point particularly on which we differ, and that is the question of responsibility of mill operations for the inherent defect which leads to transverse fissures.

Waring and Hofammann, of the Altoona Laboratory of the Pennsylvania Railroad System pointed out the presence of a shattered zone of metal in nearly every case of rail failure displaying transverse fissure. Mr. Howard says transverse fissures have been found outside of those zones, but in the great majority of the examinations made these transverse fissures are accompanied by these shattered zones. Further investigation is needed.

The main point in the problem is, however, the overstraining of the metal in the head of the rail by the severity of service and the probability of increasing severity. We have changed from iron rail to Bessemer steel rail and now to Open-hearth rail. We are now recognizing the necessity for using the tougher and more resistant high manganese steel rail on the sharp curves where the traffic is especially heavy.

In addition, we have laid before the steel manufacturers the question of heat treated carbon steel rails in order to ascertain on what conditions they believe they can furnish such rails for use in our heavy service tracks between New York and Pittsburgh, because of the considerable increase in the elastic limit of such material. Mr. Howard makes the following quotation from the presidential address of A. W. Gibbs, before the American Society for Testing Materials, in 1915. « Tersely stated, it means heavier loads and more of them. This is a path once entered upon, admits of no turning back. »

Inasmuch as economy in transportation has been brought about by large capacity unit of rolling stock, the roadway on which those units are carried must be made strong enough for its duty.

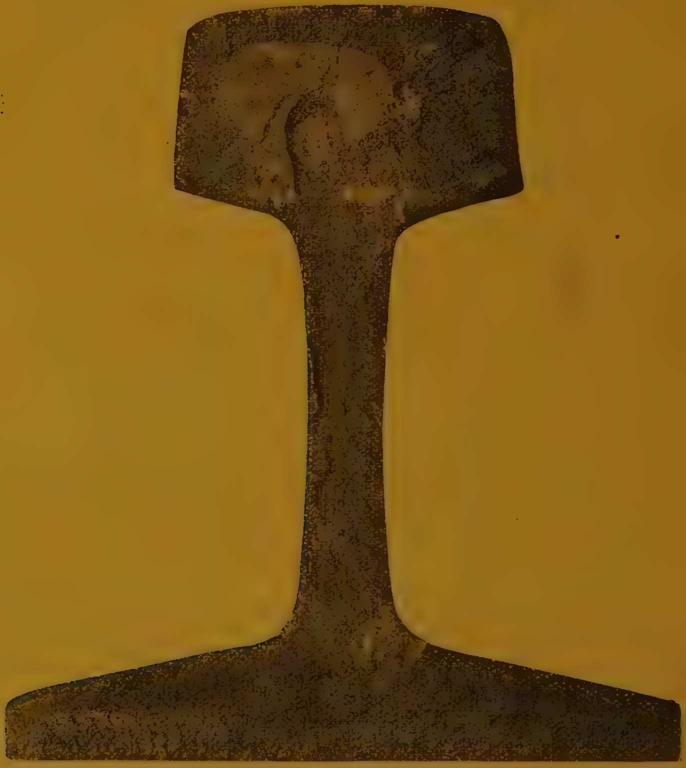
The engineer physicists and chemists of the railroads have given deep and prolonged study to the fundamental cause of the transverse fissure which, doubtless, is developed in service as described by Mr. Howard, and, after research of many hundreds of samples, chemically, microscopically, physically and metallurgically, Dr. McDonnell and Mr. Waring, of the Altoona Laboratory of the Pennsylvania Railroad System, are quite convinced that the source of the defect is thermal and not chemical. Almost every case examined by the diagonal section deep etching tests show the presence of many internal cracks, which are believed to be incident to the process of manufacture. A splendid typical example of a transverse fissure, together with the shattering cracks disclosed by the deep etching tests in the longitudinal section, is illustrated herewith, figures 10 and 11. Chemically, the material is homogeneous, without any segregation, and the sulphur print shows a uniform and fine-grain texture. It happens to have a high silicon content, but these failures are found in rails with low silicon as well as high. The tracks is high speed, and the annual gross tonnage per mile of track carried is 10 776 000, about half the amount of the heaviest traffic division of the Pennsylvania Railroad System. With this, there is very little top surface wear on the head of the rail.

In studying « Transverse Fissure » failures in order to develop a rational plan for dealing with them, we have brought to light the following very important facts :

(*a*) The conditions conducive to « Transverse Fissure » failures are likely to persist through two or more consecutive melts. In one case six consecutive melts had from three to seven « Transverse Fissure » failures;

(*b*) The « Transverse Fissure » failures are not likely to be confined to certain ingots. The four failures from one melt were all from different ingots, and no instance was found where all the failures from a melt were from the same ingot. In Melt No. 52009, « Transverse Fissures » were found in at least six ingots, as determined by six of the failures having occurred in the « F » rail as follows :

« A »	0
« B »	1
« C »	3
« D »	2
« E »	3
« F »	6
Total. . .	15



100 lb. P. S. Laid : 2-1917. Removed : 12-12-23.
In service 6 years, 10 months in tangent track.

	Open-hearth						
Borings.	C.	Mn.	P.	Si.	S.	Average Brinell hardness.	Position
Head « O ». . .	0.649	0.90	0.042	0.286	0.041	257	in ingot « F «.
Web « M ». . .	0.647	0.90	0.039	0.282	0.040	247	

Fig. 10. — Original fracture.

There is always a possibility of the letters « E » and « F » being confused in reporting.

The fact that the conditions conducive to « Transverse Fissures » are likely to proceed through two or more consecutive melts is a strong proof that the conditions of manufacture are very variable, a period of bad work running through several melts, and that during the period of bad work defects occur in the process of manufacture which lead to ultimate failure in service in the tracks.

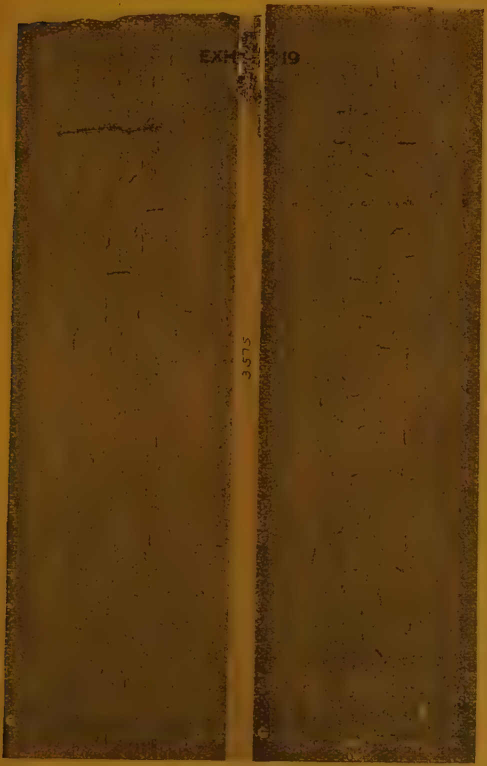


Fig. 11.
Longitudinal sections deep etched.

The American Railway Engineering Association committee has collected statistical information of transverse fissure failures covering about one half of the mileage of American railway track, and found that 5 362 simple transverse fissures were divided among the different positions in the ingot from the top down as follows :

Rail letter.	Simple transverse fissures.
A.	1 419
B.	1 243
C.	984
D.	951
E.	347
F.	241
G.	177
Total. . .	5 362

These indicate at least that, although they occur in any part of the ingot, the upper segregated and less dense and non-homogeneous part is by far the most subject to the defect.

During the twenty-one years from 1902 to 1922 inclusive, 11 199 fissures have developed from 7 846 melts produced by the various mills, a ratio of 1.4 fissures per melt.

Another group of statistics show that only one melt in ten sold to the reporting railways produced any transverse fissure, or about 1-1/2 % of the rail melts, a chance of 1 to 65.

Taking the full number of rails in the tracks of the reporting railways, 37 000 000, there has been one transverse fissure failure to 3 300 rails in service.

The mass of failures is grouped by certain periods of production at certain mills, not only in periods of years, but are narrowed down to specific heats. Then some change in mill practice occurs, and the rate of failures is entirely changed. One mill through a period of twenty-one years, by a voluntary discard from the top of the ingot of

25 % had only 120 simple transverse fissures in its rails, while another mill with different mill practice had 1 537. The rails of the first mill carried the heaviest traffic on the continent, while a large proportion of those of the alternate mill were under a much more limited traffic.

In view of the statement made in the Interstate Commerce Commission report, previously referred to, that « a relation exists between rails of high carbon content and the formation of transverse fissures », it should be noted that in the case of 2 020 fissures they were evenly divided between ranges of carbon 0.58 to 0.70 % (low carbon), and 0.71 to 0.90 % (high carbon). One railroad in particular found the ratio 3 to 1 of low carbon to high carbon.

Only one transverse fissure failure occurs in a single melt in the large proportion of cases, though in some melts 27 have been found.

For the sake of comparison, an examination of 2 000 melts of various manufacturers by one railroad company, covering failures of all kinds, transverse fissures, as well as other defects, that have occurred in one melt during a period of ten years two months, disclosed the following proportions :

TABLE 6.

Number of rail failures per melt in 2 000 melts.

1 630 melts, or	81.50 % of the total melts examined, had	1 failure.
228 — —	11.40 % — — — —	2 —
64 — —	3.20 % — — — —	3 —
33 — —	1.65 % — — — —	4 —
15 — —	0.75 % — — — —	5 —
11 — —	0.55 % — — — —	6 —
7 — —	0.35 % — — — —	7 —
7 — —	0.35 % — — — —	8 —
1 — —	0.05 % — — — —	9 —
0 — —	0.00 % — — — —	10 —
3 — —	0.15 % — — — —	11 —
1 — —	0.05 % — — — —	19 —

On the subject of co-operation of the trunk line railroads and the steel mills mentioned in the report, the preliminary steps have been taken to increase the activity in joint study, which has been carried on for many years to their mutual advantage.

The key-note of the report is the severe stress imposed upon the rail by the great traffic and heavily concentrated axle-loads of the rolling stock. That these are greater than in any other place in the world cannot be gainsaid. The accompanying tabulated statement of traffic of the principal railroads for the year 1923 (table 7), is a remarkable exhibit of transportation importance. It shows that the Pennsylvania Railroad System carries the business of three of the most important railroad systems between the Mississippi River and the Pacific Coast on one-third their combined mileage, creating an unsurpassed traffic density.

TABLE 7.

Operating statistics of large steam railroads: for the year 1923 having operating revenues above $25 000 000.

(From *Railway Age.*)

Index number.	—	Average miles of road operated.	Annual freight traffic.		Annual passenger train miles.
			Train miles.	Gross ton miles excluding locomotive and tender.	
1	Pennsylvania Railroad System.	10 894	59 894 104	106 298 624 000	62 639 778
2	New York Central (includes Michigan Central, C. C. C. & St. Louis, & Pittsburgh & L. E.)	10 904	46 769 114	95 337 269 000	48 288 373
3	Illinois Central (includes Central of Georgia)	8 097	27 656 467	44 326 262 000	22 169 102
4	Baltimore & Ohio	...	...	...	...
5	Atchison, Topeka & Santa Fe (includes Gulf, Colorado & Santa Fe)	11 776	24 272 739	38 179 645 000	23 381 616
6	Southern Pacific (includes lines in Texas & Louisiana).	10 635	23 747 912	36 600 521 000	23 478 633
7	Union Pacific (includes Oregon Short Line & Oregon-Washington Railroad & Nav.)	8 256	21 583 571	33 973 603 000	26 818 676
8	Chicago, Burlington & Quincy.	9 334	20 764 946	33 300 529 000	18 118 706
9	Chicago, Milwaukee & St. Paul	11 007	21 649 558	30 982 922 000	17 634 753
10	Erie Railroad	2 309	12 934 838	26 624 085 000	7 622 649
11	Chicago & Northwestern.	8 456	20 289 792	26 048 210 000	18 916 974
12	Chesapeake & Ohio.	2 553	10 934 471	25 170 482 000	6 534 559
13	Louisville & Nashville	5 028	20 336 983	23 648 984 000	12 327 406
14	Norfolk & Western	2 228	10 286 483	22 405 375 000	4 828 330
15	Southern Railway	6 942	18 590 275	21 990 715 000	15 781 761
16	Great Northern.	8 254	12 281 236	21 188 310 000	11 641 175
17	Chicago, Rock Island & Pacific	7 635	17 215 784	20 596 731 000	15 206 688
18	Missouri Pacific	7 176	13 695 840	19 064 645 000	11 077 281
19	Northern Pacific	6 420	11 008 107	17 968 016 000	9 822 837
20	Philadelphia & Reading	1 120	8 434 851	14 168 929 000	6 110 877
21	Wabash	2 418	7 688 362	11 848 813 000	5 651 833
22	Lehigh Valley	1 317	6 967 591	11 728 205 000	4 184 988
23	Atlantic Coast Line	4 861	9 091 658	11 415 732 000	9 397 482
24	New York, Chicago & St. Louis	1 448	7 538 364	11 383 072 000	2 184 632
25	St. Louis & San Francisco.	4 683	10 547 929	11 354 255 000	8 860 645
26	Delaware, Lackawanna & Western . .	993	6 465 424	10 708 912 000	5 864 623
27	Boston & Maine	2 455	7 344 963	8 039 012 000	10 078 237
28	Delaware & Hudson	886	4 220 793	7 884 516 000	2 375 516
29	New York, New Haven & Hartford . .	1 974	6 029 268	7 368 292 000	12 316 064
30	Seaboard Air Line	3 552	6 130 643	7 286 518 000	7 084 031
31	Pere Marquette.	2 190	4 890 410	6 770 525 000	3 306 107
32	Chicago & Alton	1 010	4 112 958	5 797 119 000	3 449 608
33	Central Railroad	695	3 541 688	5 102 977 000	4 293 044
34	Chicago & Eastern Illinois.	945	2 976 541	4 586 606 000	2 760 470
35	Boston & Albany.	394	3 655 763	3 689 116 000	3 668 073
36	Long Island	393	576 240	436 583 000	2 473 643

Some of the most recent heavy locomotives, all freight except the two last, are named below (table 8):

TABLE 8.

Railroad.	Service.	Weight (excl. tender), in lb.	Pounds on driver axle	Rated tractive effort.	Type.
Baltimore & Ohio	Freight.	436 510	69 446	84 260	2-10-2
Union Pacific	—	378 000	59 000	70 450	2-10-2
Southern Pacific	—	398 000	(1) 61 980	(2) 75 150	2-10-2
Illinois Central	—	382 000	61 500	73 800	2-10-2
Great Northern	—	422 340	68 500	87 000	2-10-2
Pennsylvania	—	386 100	71 500	90 024	2-10-0
Pennsylvania	Passenger.	385 000	69 500	64 550	4- 8-2
Southern Pacific (3)	—	368 000	61 500	67 660	4- 8-2

(1) 62 460 lb. on trailer.
(2) 85 350 lb. with booster.
(3) This locomotive makes the entire run between El Paso, Texas, and Los Angeles, California, 815 miles with a 12-car train.

Rail designs.

It will be seen from the preceding that, for a period of twenty years, 1873 to 1893, the engineering societies concentrated their study upon the design for a rail which would give the best service from the points of view of resistance to wear, breakage and crushing.

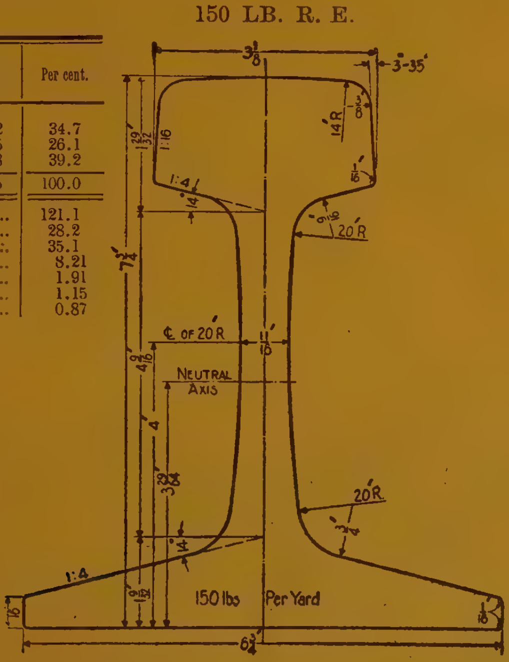
A period of « watchful waiting » succeeded in order to determine the results of the work, lasting until 1899, after which the whole problem of the rail, including design and specifications, was resumed with increased effort and has been continued for twenty-five years. This is a co-ordinated and united effort and will be carried on indefinitely in order to take advantage of the improvements found desirable from time to time by reason of the progress of the art.

The present period has witnessed the passing of Bessemer steel for principal rail manufacture, and the general use, almost universal, of Open-hearth steel in its stead, and the introduction of the heavy base and better balanced R. E. rail designs. The recommended designs of the American Railway Engineering Association and of the American Railway Association, its sponsor, together with a few of the independent designs of other railroads are illustrated herewith, comparisons being made between the two nearest designs in each illustration (figs. 12 to 23).

Since the introduction of the heavy base designs, the base failures have been reduced to a very small number, but it will be observed that the New York Central Lines maintain the use of the thin base from the point of view that the change in material from Bessemer to Open-hearth steel produced a stronger steel and made it unnecessary to thicken the base as well. It may not be considered as definitely settled as yet, because it is based on a metallurgical problem which has not been solved with general satisfaction.

In view of the important facts which have been set forth in this note upon rail service, culminating in the high duty imposed on massive loads and extraordinary traffic upon a material of limited strength, it appears to the Reporter that we are driven pretty hard to discover such improvement as can be made in the manufacture of rail steel to keep up with the advancing punishment. We ought really to get ahead of it and not be in the position of always trying to « catch up » as seems to have been the state of affairs for many years, as may be appreciated from the account of the several concerted efforts made by the engineers to keep up with the business requirements.

AREA.	Square inches.	Per cent.
Head	5.12	34.7
Web	3.85	26.1
Base	5.78	39.2
Total...	14.75	100.0
Moment of inertia		121.1
Section modulus head		28.2
— — base		35.1
Ratio moment of inertia to area		8.21
— section modulus to area		1.91
— height to base		1.15
— base to height		0.87



Recommended design for 150 lb. rail section.
Fig. 12.

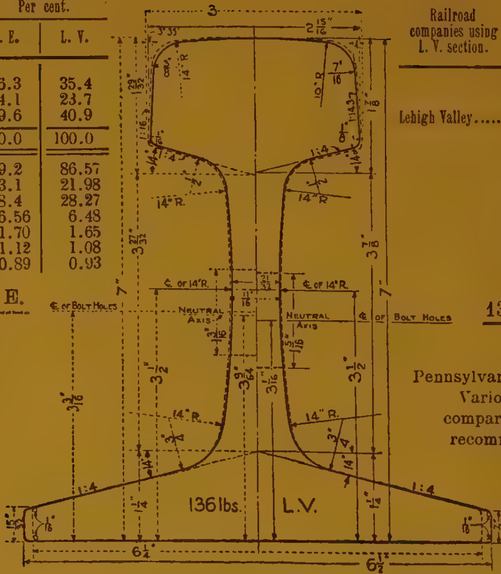
Heavy rail designs.

An important step in the effort for improvement was the jump from the use of a 100-pound rail to the heavier weights, 130, 135 and 136 pounds per yard, whereas, up to that period, the increases were made in steps of 5 to 10-pounds per yard.

The first of these heavy sections was the 135-pound rail of the Central Railroad Company of New Jersey (fig. 14), which was rolled in 1910 for use on very sharp curves (10° to 14°), where the traffic was heavy. About 40 miles are in use, but no more will be ordered, as it is the intention of the company to lay 130-pound R. E. instead.

AREA.	Square inches.		Per cent.	
	R. E.	L. V.	R. E.	L. V.
Head........	4.93	4.72	36.3	35.4
Web........	3.28	3.17	24.1	23.7
Base........	5.37	5.46	39.6	40.9
Total...	13.58	13.35	100.0	100.0
Moment of inertia..................			89.2	86.57
Section modulus, head.............			23.1	21.98
— — base.............			28.4	28.27
Ratio moment of inertia to area....			6.56	6.48
— section modulus to area......			1.70	1.65
— height to base................			1.12	1.08
— base to height................			0.89	0.93

140 lb. R. E.



Railroad companies using L. V. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
Lehigh Valley.....	68 330 lb.	68 330 lb.

136 lb. L. V.

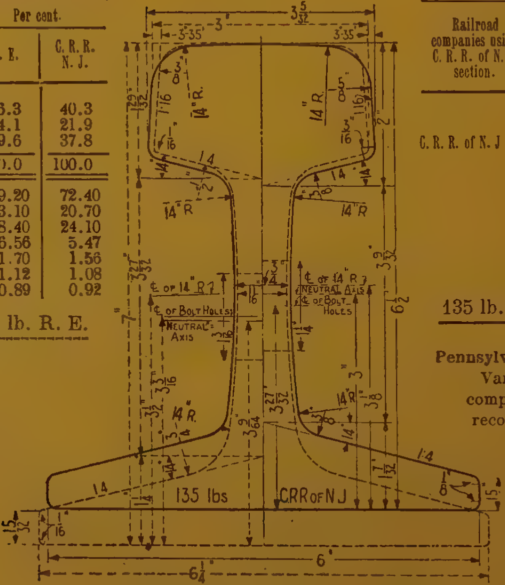
Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 140 lb. R. E.

Fig. 13.

AREA	Square inches.		Per cent.	
	R. E.	C. R. R. N. J.	R. E.	C. R. R. N. J.
Head	4.93	5.33	36.3	40.3
Web.........	3.28	2.90	24.1	21.9
Base.........	5.37	5.00	39.6	37.8
Total...	13.58	13.23	100.0	100.0
Moment of inertia			89.20	72.40
Section modulus, head...............			23.10	20.70
— — base...............			28.40	24.10
Ratio moment of inertia to area....			6.56	5.47
— section modulus to area			1.70	1.56
— height to base................			1.12	1.08
— base to height................			0.89	0.92

140 lb. R. E.



Railroad companies using C. R. R. of N. J. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
C. R. R. of N. J ...	62 300 lb.	65 800 lb.

135 lb. C. R. R. of N. J.

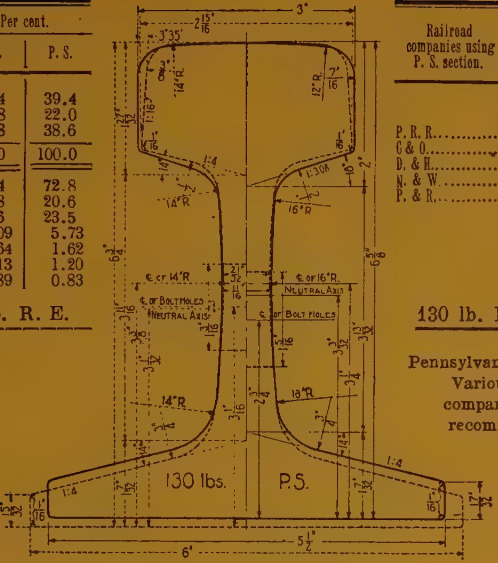
Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 140 lb. R. E.

Fig. 14.

AREA	Square inches.		Per cent.	
	R. E.	P. S.	R. E.	P. S.
Head	4.63	5.0	36.4	39.4
Web	3.02	2.8	23.8	22.0
Base	5.06	4.9	39.8	38.6
Total	12.71	12.7	100.0	100.0
Moment of inertia			77.4	72.8
Section modulus, head			20.8	20.6
— — base			25.6	23.5
Ratio M. I. to area			6.09	5.73
— section modulus to area			1.64	1.62
— height to base			1.13	1.20
— base to height			0.89	0.83

130 lb. R. E.



Railroad companies using P. S. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
P. R. R.	72,600 lb.	75 600 lb.
C & O.	63 820 lb.	61 167 lb.
D. & H.	64 200 lb.	67 000 lb.
N. & W.	59 000 lb.	63 500 lb.
P. & R.	67 200 lb.	64 400 lb.

130 lb. P. S.

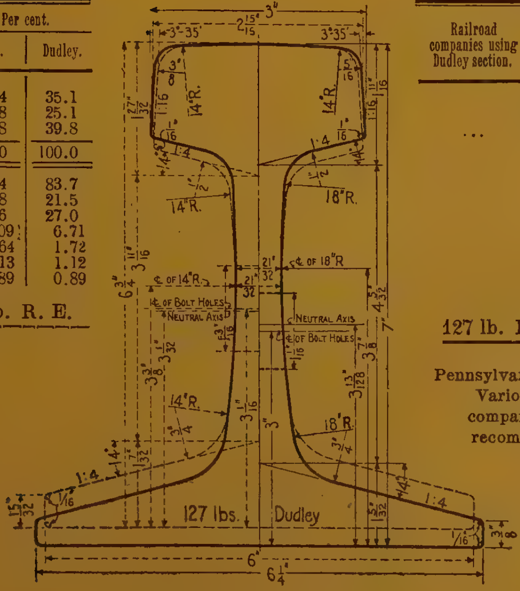
Pennsylvania Railroad System
Various rail sections
compared with AREA
recommended designs.

Compared with 130 lb. R. E.

Fig. 15.

AREA.	Square inches.		Per cent.	
	R. E.	Dudley.	R. E.	Dudley.
Head	4.63	4.38	36.4	35.1
Web	3.02	3.14	23.8	25.1
Base	5.06	4.96	39.8	39.8
Total	12.71	12 48	100.0	100.0
Moment of inertia			77.4	83.7
Section modulus, head			20.8	21.5
— — base			25.6	27.0
Ratio M. I. to area			6.09	6.71
— section modulus to area			1.64	1.72
— height to base			1.13	1.12
— base to height			0.89	0.89

130 lb. R. E.



Railroad companies using Dudley section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
...	...	...

127 lb. Dudley.

Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 130 lb. R. E.

Fig. 16.

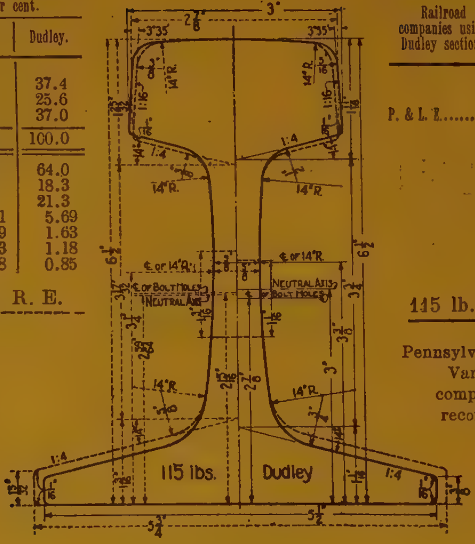
AREA.	Square inches.		Per cent.	
	R. E.	Dudley.	R. E.	Dudley.
Head.........	4.40	4.20	37.1	37.4
Web.........	2.69	2.88	22.7	25.6
Base.........	4.76	4.16	40.2	37.0
Total...	11.85	11.24	100.0	100.0
Moment of inertia..................			67.6	64.0
Section modulus, head.............			18.9	18.3
— — base.............			23.1	21.3
Ratio moment of inertia to area...			5.71	5.69
— section modulus to area....			1.59	1.63
— height to base..............			1.13	1.18
— base to height..............			0.88	0.85

120 lb. R. E.

Railroad companies using Dudley section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
P. & L. E..........	59 000 lb.	75 000 lb.

115 lb. Dudley.

Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.



Compared with 120 lb. R. E.

Fig. 17.

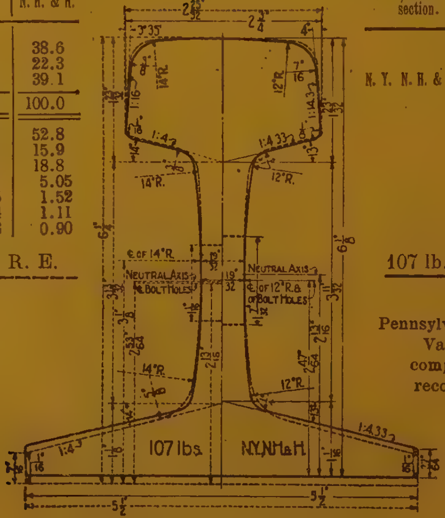
AREA.	Square inches.		Per cent.	
	R. E.	N. Y. N. H. & H.	R. E.	N. Y. N. H. & H.
Head.........	3.80	4.02	37.4	38.6
Web.........	2.25	2.37	23.0	22.3
Base.........	3.90	3.86	39.6	39.1
Total...	9.95	10.25	100.0	100.0
Moment of inertia..................			57.0	52.8
Section modulus, head............			16.7	15.9
— — base.............			20.1	18.8
Ratio moment of inertia to area...			5.27	5.05
— section modulus to area....			1.55	1.52
— height to base..............			1.14	1.11
— base to height..............			0.88	0.90

100 lb. R. E.

Railroad companies using N. Y., N. H. & H. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight
N. Y. N. H. & H..	56 100 lb.	63 035 lb.

107 lb. N. Y., N. H. & H.

Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

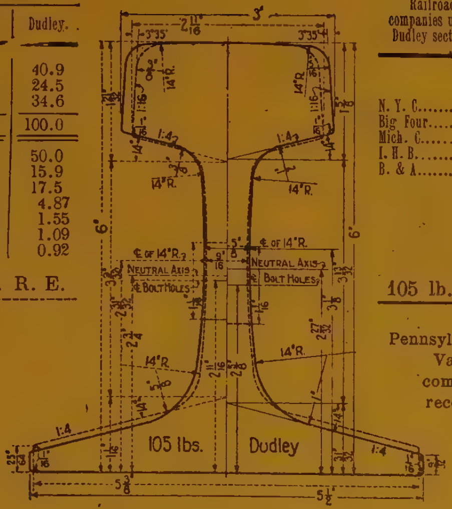


Compared with 110 lb. R. E.

Fig. 18.

AREA.	Square inches.		Per cent.	
	R. E.	Dudley.	R. E.	Dudley.
Head....	3.80	4.20	38.2	40.9
....	2.25	2.51	22.6	24.5
Base.........	3.90	3.57	39.2	34.6
Total...	9.95	10.28	100.0	100.0
Moment of inertia....................			49.0	50.0
Section modulus, head..............			15.1	15.9
— — base...............			17.8	17.5
Ratio moment of inertia to area....			4.92	4.87
— section modulus to area			1.52	1.55
— height to base,................			1.12	1.09
— base to height................			0.90	0.92

100 lb. R. E.



Railroad companies using Dudley section.	Maximum locomotive axles weight run over rail.	
	Passenger.	Freight.
N. Y. C............	62 000 lb.	63 100 lb.
Big Four..........	62 000 lb	63 100 lb.
Mich. C...........	62 000 lb.	63 100 lb.
I. H. B............	...	60 400 lb.
B. & A............	52 500 lb.	59 100 lb.

105 lb. Dudley.

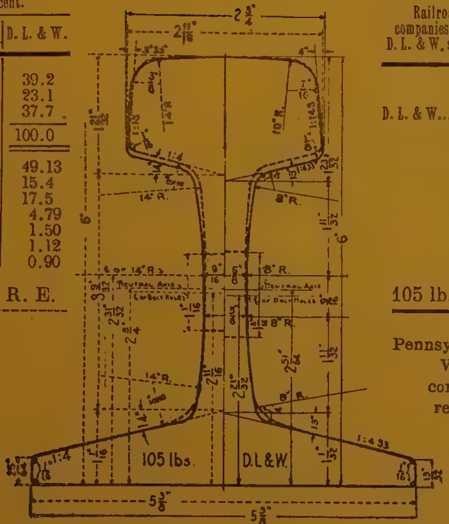
Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 100 lb. R. E.

Fig. 19.

AREA.	Square inches.		Per cent.	
	R. E.	D.L. & W.	R. E.	D. L. & W.
Head.........	3.80	4.02	38.2	39.2
Web.........	2.25	2 37	22.6	23.1
Base.........	3.90	3.86	39.2	37.7
Total...	9 95	10.25	100.0	100.0
Moment of inertia.....................			49.0	49.13
Section modulus, head...............			15.1	15.4
— — base...............			17.8	17.5
Ratio moment of inertia to area. ..			4.92	4.79
— section modulus to area.......			1.52	1.50
— height to base................			1.12	1.12
— base to height................			0.90	0.90

100 lb. R. E.



Railroad companies using D. L. & W. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
D. L. & W.........	66 700 lb.	68 400 lb.

105 lb. D. L. & W.

Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 100 lb. R. E.

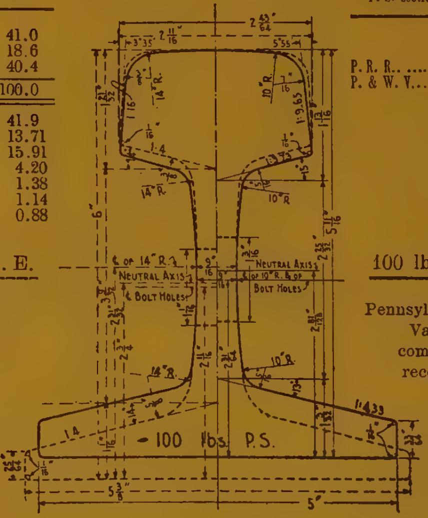
Fig. 20.

The 125-pound P. S. section of the Pennsylvania Railroad System was first rolled in 1915, but was changed to the 130-pound P. S. section in 1916 by the addition of 1/8 inch on the top of the head (fig. 15). With reference to the justification of the expense for these heavy types :

AREA.	Square inches.		Per cent.	
	R. E.	P. S.	R. E.	P. S.
Head........	3.80	4.09	38.2	41.0
Web.........	2.25	1.85	22.6	18.6
Base.........	3.90	4.03	39.2	40.4
Total...	9.95	9.97	100.0	100.0
Moment of inertia..................			49.0	41.9
Section modulus, head............			15.1	13.71
— — base..............			17.8	15.91
Ratio moment of inertia to area...			4.92	4.20
— section modulus to area....			1.52	1.38
— height to base..............			1.12	1.14
— base to height..............			0.90	0.88

Railroad companies using P. S. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
P. R. R..	72 600 lb.	75 600 lb
P. & W. V........	55 400 lb.	55 400 lb

100 lb. R. E.



100 lb. P. S.

Pennsylvania Railroad System.
Various rail sections
compared with AREA
recommended designs.

Compared with 100 lb. R. E.

Fig. 21.

Rail service value is determined by :

1° Rail failures;

2° Rail life;

3° Comparative cost of labor maintenance.

1° *Rail failures.*

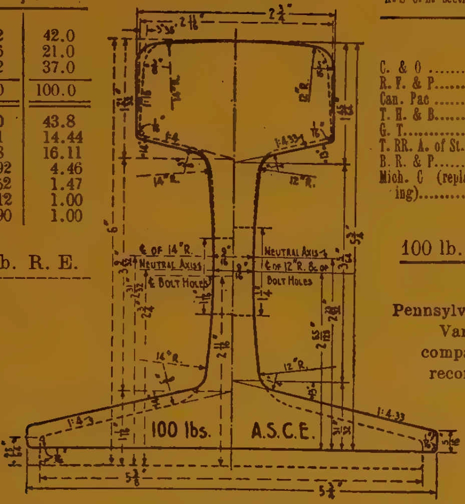
It has been pretty well determined from the study of our records that the rail failures in 100-pound rail are from two to two and one-half times as many as in the 130-pound.

2° *Rail life.*

The comparative records of rail life are more general than in the case of rail failure records, as the comparisons have in some instances been rather roughly made, some elements which necessarily enter into such comparisons as important factors not having been recorded owing to the difficulty and expense of obtaining complete data. The reports from different portions of the System, therefore, are somewhat conflicting and a little more difficult to harmonize. By comparing the different kinds of rail which have been laid consecutively on the same sharp curves and keeping re-

AREA.	Square inches.		Per cent.	
	R. E.	A.S.C.E.	R. E.	A.S.C.E.
Head.	3.80	4.13	38.2	42.0
Web.........	2.25	2.06	22.6	21.0
Base.........	3.90	3.63	39.2	37.0
Total...	9.95	9.82	100.0	100.0
Moment of inertia..................			49.0	43.8
Section modulus, head.............			15.1	14.44
— — base.............			17.8	16.11
Ratio moment of inertia to area....			4.92	4.46
— section modulus to area.....			1.52	1.47
— height to base...............			1.12	1.00
— base to height..............			0.90	1.00

100 lb. R. E.



Railroad companies using A. S C. E. section.	Maximum locomotive axle weight run over rail.	
	Passenger.	Freight.
C. & O	63 820 lb.	61 167 lb.
R. F. & P..........	63 833 lb.	63 833 lb.
Can. Pac	49 000 lb.	49 000 lb.
T. H. & B..........	48 500 lb.	46 800 lb.
G. T................	59 500 lb.	53 895 lb.
T. RR. A. of St. L.	74 600 lb.	75 600 lb.
B. R. & P..........	62 550 lb.	61 200 lb.
Mich. C (replacing)............	61 500 lb.	61 250 lb.

100 lb. A. S. C. E.

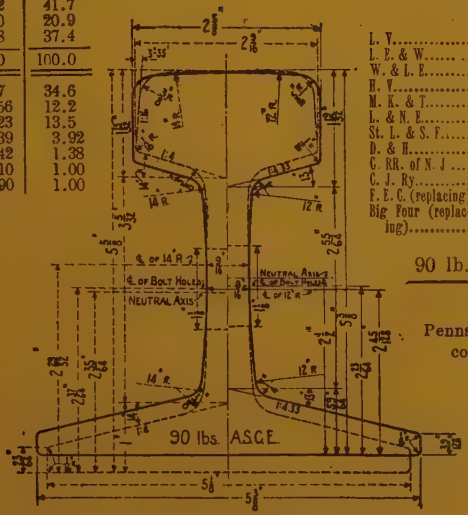
Pennsylvania Railroad System.
Various rail sections
compared with AREA.
recommended designs.

COMPARED WITH 100 LB. R. E.

Fig. 22.

AREA.	Square inches.		Per cent.	
	A.R.A.A.	A.S.C.E.	A.R.A.A.	A S.C.E.
Head.........	3.20	3.71	36.2	41.7
Web.........	2.12	1.85	24.0	20.9
Base	3.50	3.27	39.8	37.4
Total...	8 82	8.83	100.0	100.0
Moment of inertia...			38.7	34.6
ection modulus, head.............			12.56	12.2
— — base.............			15.23	13.5
Ratio moment of inertia to area....			4.39	3.92
— section modulus to area......			1.42	1.38
— height to base...............			1.10	1.00
— base to height..............			0.90	1.00

90 lb. A.R.A-A.



Railroad companies using A. S. C. E. section.	Maximum locomotive axle weight run over rail.		Bolt holes.	
			Distance to axlé base.	Diameter.
	Passenger.	Freight.		
L. V................	68 330 lb.	68 330 lb.	2 11/32"	1 1/16"
L. E. & W...... ..	51 000 lb.	56 900 lb.	2 45/128"	1 1/16"
W. & L. E.........	31 400 lb.	60 417 lb.	2 45/128"	1"
H. V................	47 500 lb.	61 125 lb.	2 45/128"	1"
M. K. & T.........	55 000 lb.	58 500 lb.	2 45/128"	1 1/8"
L. & N. E..........	...	52 000 lb.	2 45/128"	1 1/4"
St. L. & S. F......	68 900 lb.	63 200 lb.	2 23/64"	1 "
D. & H............	67 200 lb.	68 700 lb.	2 45/128"	1 1/8"
C. RR. of N. J	62 300 lb.	65 800 lb.	2 45/128"	1 1/16"
C. J. Ry...........	...	63 000 lb.	2 45/128"	1 1/4"
F. E. C. (replacing)	44 500 lb.	56 200 lb.	2 45/128"	1 1/8"-1 1/4"
Big Four (replacing)............	62 000 lb.	63 100 lb.	2 45 1-8"	1"

90 lb. A. S. C. E.

Pennsylvania Railroad System. Various rail sections compared with AREA recommended designs.

COMPARED WITH 90 LB. A. R. A.-A.

Fig. 23.

cord of the time of service has resulted in the estimate that the life of 130-pound rail may be from 20 to 30 % greater than that of 100-pound rail in the same case. We have cases, however, where we have eliminated defective material from 100-pound rail by our special chemical examination, which was in force for that material from 1915 until 1921, so that the 100-pound rail has given equal and even greater life than 130-pound rail, which was not subjected to the same searching examination. There are some places on the System where batter of the rail ends in the 130-pound rail occurred, whereas on other portions of the System with a very much greater density of traffic the same defect was not noticeable to any great extent. Examination of this rail showed that apparently it was soft material, carbon being as low as 0.65 %. We attribute this to defective material rather than to the weight per yard.

3° *Comparative cost of labor maintenance.*

No precise records of relative cost of maintenance have been kept, but there is a general opinion among the trackmen that there is economy in the labor maintenance of 130-pound rail over 100-pound of from 20 to 30 %, which is not always taken advantage of by reduction in forces, but in the maintenance of a better condition of track.

It is well settled in our minds that the business of this Company could no longer be carried on adequately on the 100-pound rail section, where our traffic and rolling-stock are the heaviest.

The Lehigh Valley Railroad Company began laying the 136-pound L. V. section in 1916 (fig. 13), and reports that it has records giving more than twice the life on curves under increased traffic that was obtained from the 100-pound R. A.-A section previously in use, and there are 10° curves laid with the 136-pound rail where no work was required in four years to readjust the line and surface.

Rail material required.

In spite of this large increase in rail weight, rail failures continue to occur, but with diminished frequency, and the type of failure indicates that improvement in the quality and strength of the metal is required rather than a further increase in the weight per yard.

From the study of the rail design, we find now that our effort must be concentrated upon the study of the material in order to improve it in such a fashion that it will be suitable for absorbing its peculiar stresses and transmitting the super-imposed weights to the road-bed with perfect safety. *We are on the eve of another period of research, and this time into the material of construction which goes to make up the rail.*

The use of various alloys has been considered, high manganese, nickel and chromium, but without heat-treatment the alloys are not used to their best advantage. Nickel and chromium in rail steel have been tried by several railroads without heat-treatment, but the result was indifferent, the failures in some cases being greater than for carbon steel, perhaps because the right proportions may not have been introduced. The amount of nickel alone which has been used was 3.25 to 5.00 %. The amounts of chromium and nickel together have been 2 to 2-1/2 % nickel with 0.50 to 0.90 chromium in some instances, and in others somewhat less. As chromium is a hardener, and nickel a toughener metal, the combination ought to be good, but in all probability they require heat-treatment to bring out the good effects, as is the case with motor-car steel.

Manganese steel is valued mostly for its resistance to abrasion, and has been considered already in connection with rail-wear.

Rails finished in the electric furnace have been tried by some railways, but without marked advantage.

Whenever a high class steel is required for a special purpose, it is made generally from ingots which were teemed with the assistance of a sink-head, with the large end of the ingot up, as it keeps the upper end hot, conducing to more uniform cooling which lessens segregation and makes sounder and denser steel. Trials of rail steel prepared in this way in 1914 and 1915 have been made with good results. There were only 171.5 failures per 100 miles of track of sink-head rail against 415.4 of ordinary Open-hearth rails per 100 miles of track, but the most satisfactory part of the record is that there were only 63 broken sink-head rails per 100 miles of track against 200.6 broken ordinary Open-hearth rails per 100 miles of track, showing that not only does the sink-head method help to lessen head failures, but has such an effect throughout the entire ingot as to reduce the breakage as well.

It should be advantageous to use the oxidizers titanium, vanadium, silicon and aluminium, which act as scavengers to make steel more homogeneous, in conjunction with the sink-head, for the latter would help to nullify the tendency of the former to form a deeper pipe.

The production of the Sandberg Sorbitic microstructure by hardening and toughening the upper part of the head, which must undergo the greatest severity of service, by cooling it more rapidly than normal by means of an air-blast controlled and directed so as to bring about the cooling in the desired portion of the head, is being tried in service by several companies, and, while in general it is reported that the abrasion of the head is somewhat less than in the case of Open-hearth rail, it is not considered that they have been sufficiently long in service to make definite pronouncement.

This seems to be a sort of partial heat-treatment which does not appear to the Reporter to bring about sufficient improvement in the metal to meet the demands of the service required by the conditions of the period which is now at hand. *There is the utmost necessity for great and radical steps forward.*

Twenty-five years of work upon the improvement of the specifications have not brought the result required. Many changes have been introduced which have been beneficial, *but the great improvement, which is increased strength and ductility to the extent necessary, has not been reached.*

Heat-treated rails.

To attain this, study brings us back every time to the heat-treated steel. Trials of heat-treated 100-pound and 125-pound rails, prepared at the Altoona Shops of the Pennsylvania Railroad System, and by two or three of the manufacturers, have been made in the tracks of that System with encouraging results.

At the works, compared with untreated, treated rail, water quenched at 840° C. and annealed for two hours at 450° C. gave an increase of :

1° Elastic limit of 69 % ;
2° Ultimate strength of 32 % ;
3° Elongation : Nothing.
4° Reduction of area : 50 % ;
5° Bending capacity of 93 % ;
6° Resistance to impact : over 89 %.
So tough stopped pendulum;

7° Resistance to transverse bends of 80 %. Elastic limit was 17 % greater than of 125-pound rail with 25 % more metal and 20 % higher in carbon;

8° Blows in drop test of 14 %;

9° Total ductility in drop test of 25 %;

10° Stiffness in drop test of 24 %.

Another lot gave :

Elastic limit, 110 066 pounds per square inch;

Tensile strength, 168 600 pounds per square inch;

Elongation % in inches : 9.0;

Reduction in area : 15.4 %.

Thus the strength required, as previously noted, is attained at once.

Again, in the service trials there is a decided improvement in the resistance to abrasion from wheels of heat-treated steel rails amounting to from 12 to 64 % less wear. In the lots carefully prepared, there was but one broken rail.

It appears, therefore, that heat-treatment of rail-steel promises greater resistance to wear, and a stronger metal to bear up under the loads, thus avoiding the breaking down of the structure of the present carbon steel rails in use, and probably at not much greater cost than carbon steel rails.

It is realized that the trials up to the present time are of limited quantity, but the manufacturers have been requested by the Pennsylvania Railroad System to make such additional experiments as will enable a decision to be reached upon the practicability of placing the manufacture upon a commercial basis.

It is believed that the care required in heat-treatment will make it necessary to introduce into rail steel production other practices for the better, such as the use of the sink-head with the large end of the ingot uppermost, etc.

Rail specifications.

In the meantime, while making these studies for a stronger and better steel rail, it is necessary to keep our specifications for carbon steel rail up to the degree of excellence necessary to obtain the best rail that can be produced under current methods of manufacture.

Under the rolling stock of the present day the stresses induced in rails have mounted up to and beyond the elastic limit of the material.

By present manufacturing methods rail steel varies considerably in quality in single ingots. The most of the causes of weakness are near the top of the ingot were segregation abounds and rails are subject to failure in lesser degree than when they are produced from the other portions of the ingot.

As the greater number of failures is in the segregated portion, so in order to obtain the best product for heavy service, the specification requirements for testing and inspection has been made more rigorous. This results in a larger percentage of rejections, for which the manufacturers require us to pay. They will allow us to make our tests and inspection as severe as we like (barring complete rejection) as long as we pay for it, but the extra charge has been placed so high that it has become too burdensome to accept.

Therefore, the plan has been devised of taking rail with signs of segregation and internal defect as X-Rayl classification when it passes the physical requirements. We advocate this because it is more economical to receive it and sell it if we have more than can be used economically, rather than pay the price of rejection.

In the lower classification rails are the No. 2, the X-Rayl and the « A » rails.

besides the « De-Graded » rails of a heat which has been in service and found defective and uncertain by having too many failures.

We look upon the No. 2 rails as the safest of the lot, because their classification comes from roughness and surface imperfections, and possible low point in the deflection, not impairing their safety.

The X-Rayl may come from any part of the ingot, principally from the « A » or « B » or « C » rails, as the remainder is not usually tested. A few might come from the lower portion through discovery in the bolt hole drillings or at the ends.

The « A » rails come from the poorest part of the ingot and are the most likely to be defective, segregated and brittle. It is true that not all « A » rails are bad, but they have the most bad company. However, they receive two tests, that of the « drop » (or falling weight), and the nick-and-break, so that in point of service assignment, we class them with the No. 2 rails.

Now, in order to select the best of the material for our advancing requirements on our great traffic bearing trunk lines, it is right and necessary that the low classes of rails should be excluded. We come, therefore, to the plan of *Inspection and Acceptance of Rails by Classification.*

Inspection is the degree of rejection, and the percentage or rejection fixes the price.

In order to avoid the issue of extra price, which is usually above actual extra cost we propose in the specifications suggested herewith (Exhibit 4), to purchase the X-Rayl material and select the places for its use where the service will be in proportion to its severity.

The main object in all of this is to select the best and safest rails for our heavy trunk lines, and the above is the plan worked out after years of study for accomplishing it. The question of the amount of these lower classification rails is a secondary one. If we get too many for the selected service, then the surplus should be sold and we will yet be better off financially than by paying the new price for their rejection. If, however, improvements in manufacture continue, the rails of lower classification will diminish, and that is an improvement we are trying to bring about. We believe very strongly that changes in manufacture can be made which will bring about decided improvement and result in less rejection, such as the sink-head method combined with ingot casting with the large end up.

EXHIBIT 4.

KEYSTONE RAILROAD SYSTEM.

Specification for carbon steel rails.

(130 pound and 100 pound weights.)

APPLIANCES OR ARTICLES.

Scope. — 1. These specifications prescribe the chemical and physical properties intended for the material of the finished carbon steel rails manufactured according to the standard rail cross-section design of the Keystone Railroad System, and the tests required for proving their fulfilment.

Material. — 2. The material shall be steel made by the basic Open-hearth process.

CHEMICAL REQUIREMENTS.

Chemical composition. — 3. (*a*) The chemical composition of the steel from which the rails are rolled shall be within the following limits:

Elements.	100 pound section.	130 pound section.
	Per cent.	Per cent.
Carbon. . . .	0.62 to 0.75	0.68 to 0.87
Phosphorus . .	Not to exceed 0.04	Not to exceed 0.04
Manganese . .	0.60 to 0.90	0.60 to 0.90
Silicon (minim.).	0.10	0.10

(*b*) It is desired that the percentage of carbon in an entire order of rail shall average as high as the mean percentage between the upper and lower limits specified.

(*c*) In the event of nickel and chromium being present to the extent of approximately 1.00 % and 0.35 % respectively, these elements together will be considered as the equivalent of 0.07 % of carbon in the above requirements.

Analyses. — 4. In order to ascertain whether the chemical composition is in accordance with the requirements, the manufacturer shall furnish the inspectors with analyses and information in accordance with the following notes :

(*a*) For each melt of Open-hearth steel, chemical analyses shall be made from test ingots taken during the pouring of the melt, of the elements carbon, phosphorus, manganese, silicon, sulphur, and the other principal elements, such as nickel and chromium, which affect the physical properties of the steel.

(*b*) The analyses shall be made from two ladle test ingots, one representing the steel going into the regular ingots cast from the first quarter, and the other the last quarter of each melt. The methods for making the analyses shall be those most recently adopted by the American Society for Testing Materials.

(*c*) The ladle test ingots shall be of such shape and size as will induce quick sound setting of the steel.

(*d*) Drillings for analyses shall be taken not less than 1/8 inch beneath the surface of the test ingot.

(*e*) The inspector may witness the manner of obtaining the drillings for analyses.

(*f*) On the request of the inspector, the manufacturer shall furnish a duplicate portion of the test ingot or drillings for check analyses.

(*g*) The complete analyses of each melt cast for rails shall be available for the inspector as promptly as possible, and he shall always be furnished with a copy of them before the rails are shipped.

(*h*) For information only, the manufacturer shall furnish complete analyses of drillings taken from a point at the usual « O » position of the head of the drop-test-piece adjoining the top end of the « A » rail of the last full ingot rolled in each tenth heat. (The « O » location is in the upper quarter of the head near the ouside surfaces, and the « M » location at the junction of the head and web). (Fig. 9.)

PHYSICAL REQUIREMENTS.

Mechanical strength and ductility. — 5. The finished rail, represented by the test specimens must pass the following tests successfully :

—	Rail Section	
	130-lb.	100-lb.
(*a*) The non-fracture of the test specimen when struck one blow on the rail head with the base in tension by the standard tup falling freely from a height of	18 feet.	18 feet.

—	Rail Section	
	130-lb.	100-b.
(*b*) Under the impact of one or more blows of the falling tup as in (*a*), a minimum « Elongation for 1 inch » of . . . . or, for each of 2 consecutive inches of . . . . . A sufficient number of blows shall be given to determine the complete elongation of the test specimens of one out of three test specimens of a melt.	6 % 5 %	6 % 5 %
(*c*) A maximum « Permanent Set » under the impact of falling tup as in a (*a*) for No. 1 rails of . .	1-1/4 inches. (Moment of inertia = 72.8.)	2 inches. (Moment of inertia = 41.9.)

Physical qualities. — 6. Test shall be made to determine :

(*a*) Strength.

(*b*) Ductility or toughness as opposed to brittleness.

(*c*) Soundness.

Kind of tests used. — 7. The physical qualities shall be determined by :

(*a*) The « Drop Test » for strength and ductility.

(*b*) The « Test to Destruction » for soundness.

Methods of testing. — 8. (*a*) The « Drop Test » shall be made on the machine (1) adopted as standard by the American Railway Engineering Association, having :

A tup weighing 2 000 pounds and with a radius of striking face of 5 inches.

An anvil block weighing 20 000 pounds supported on springs.

Supports for the test pieces with a radius of bearing surfaces of 5 inches, made a part of and firmly secured to the anvil, and space between centres : 4 feet for 130-lb. rail and 3 feet for 100-lb. rail.

(*b*) The « Ductility » will be measured by the elongation after test between gauge marks on the longitudinal centre line of the tension-surface of the test specimens one inch apart for three inches each side of the centre of the test piece placed there before the test.

(*c*) In the « Test to Destruction », the test specimens shall be nicked and broken, for examination, in order to disclose whether the metal be sound without interior defect as indicated by seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine grained structure, except when they are made visible by the drop test, the saws or the drills (Clause 10-B) (*f*).

Test specimens. — 9. (*a*) The test pieces of rail for drop tests shall be at least two feet longer than the span between supports in the testing machine (Section 8), and shall be cut from the crop of the top rail of the ingot being tested.

(*b*) Where it is necessary to test rails lower than the first rail, the bottom of the first rail in lieu of the top of the second rail, and the bottom of the second rail in lieu of the top of the third rail will be accepted, if preferred by the manufacturer.

(*c*) The ductibility will be measured on the drop test specimens.

(*d*) Examination for interior defects will be made on drop test specimens and bolt holes and ends of finished rails.

(*e*) It is desired that after passing the hot-saws, test specimens shall be handled as nearly as possible in the same manner as the rails.

(*f*) Each test specimen shall be marked once with its heat, or melt number.

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(1) *Proceedings American Railway Engineers Association*, vol. 10-1, 1909.

(*g*) The temperature of the test specimens when being tested shall be between 60 and 100° F. (15°6 and 37°8 C.).

Description and proportion of tests. — 10. For proving the quality of a melt of steel, test specimens shall be selected from the second, middle and last full ingot of each melt rolled, and all three pieces shall undergo the complete set of physical tests as follows :

A. *Drop test.* — (*a*) The test specimens shall be placed, one at a time, upon the supports in the testing machine, head upward, and be subjected to *one impact* blow of the tup upon the head.

(*b*) A test shall be considered as *failed* when the specimen is wholly or partially fractured, under one blow, or does not yield the desired elongation under one or more blows.

(*c*) Should none of the three test specimens fail in the drop test, the entire melt will be deemed as having passed the test. (The specimens will be set aside, or passed along, for *Destruction Test* for *special classification.*)

(*d*) If any one of the test specimens of clause (*c*) fails, in the drop test, all the « A » rails from that melt shall be rejected and the following test performed :

(*e*) The specimens representing the « *B* » *rails* of the same melt shall then be tested, and if none of the three test pieces fails, all the remaining rails of the melt shall be deemed as having passed the test. (If, in the *Destruction Test* of the « *A* » *rails,* interior defects were disclosed, the « *B* » *rail* specimens will be set aside, or passed along for *Destruction Test* for *special classification.*)

(*f*) If any one of the test specimens of clause (*e*) fails in the drop test, all of the « *B rails* from that melt shall be rejected and the following test performed :

(*g*) The specimens representing the « *C* » *rails* of the same melt shall then be tested, and if none of the three test pieces fails, all the remaining rails of the melt shall be deemed as having passed the test. (If, in the *Destruction Test* of the « *B* » *rails,* interior defects were disclosed, the « *C* » *rail* specimens will be set aside, or passed along for *Destruction Test* for *special classifications.*)

(*h*) If any one of the test specimens of clause (*g*) fails in the drop test, all of the remaining rails of the melt shall be rejected.

B. *Destruction test.* — (*a*) For the purpose of classification of rails which have passed the drop test by the purchaser, the « *A* » *rails* shall be examined for interior defects, and, if none is found, no additional Destruction Tests are necessary.

(*b*) If interior defects are observed in the « *A* » *rail* specimens, all of the « A » rails shall be classed as « X-rayls », and the following examination made :

(*c*) Specimens of the « *B* » *rails* shall then be examined for interior defects, and, if none is found, no additional Destruction Tests are necessary.

(*d*) If interior defects are observed in the « *B* » *rail* specimens, all of the « *B* » *rails* shall be classed as « X-rayls », and a similar examination and disposition made of the « *C* » *rails.*

(*e*) When the « A » rails are included in the discard, the examination for interior defect need not be continued below the « C » rail.

(*f*) The *Destruction Test* entails no penalty of rejection against the manufacturer, except as provided in 18-(*c*).

BASIS OF CLASSIFICATION.

No. 1 rails. — 11. No. 1 classification rails shall be free from injurious defects of all kinds.

No. 2 rails. — 12. Rails which vary from the specifications in a manner not impairing their strength and soundness will be accepted as « No. 2 rails » in accordance with the following :

(*a*) Rails which do not contain surface imperfections in such number or of such character as will, in the judgement of the inspector, render them unfit for recognized No. 2 uses.

(*b*) Rails arriving at the straightening presses with sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet for the thick base sections and 5 inches for the thin base sections.

(*c*) Rails represented by the test specimen which had a greater permanent set than stated in clause 5-(*c*).

« *X-rayls* ». — 13. Rails which, under the drop test exhibit interior irregularites as described in clause 8-(*c*) will be accepted as « X-rayls » for use in tracks bearing minor traffic.

ACCURACY OF MANUFACTURE.

Section. — 14. The section of rails shall conform as accurately as possible to the template furnished by the railroad company. A variation in height of 1/64 inch less or 1/32 inch greater than the specified height, and 1/16 inch in width of base will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the joint bars.

Weight. — 15. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding section. A variation of 0.5 % from the calculated weight of section, as applied to an entire order, will be allowed.

Lengths. — 16. The standard length of rails shall be 33 feet, at temperature of 60° F. (15°6 C.). Ten per cent of the entire order will be accepted in shorter lengths varying by 1 foot from 32 to 25 feet. A variation of 1/4 inch from the specified lengths will be allowed, except that for 15 % of the order this variation may be 3/8 inch.

Drilling. — 17. Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the railroad company. A variation of 1/32 inch in size and location of bolt holes will be allowed.

Finishing. — 18. (*a*) All rails shall be smooth on the heads, have bases true, flat, and free from injurious guide marks and scratches, be straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than 1/32 inch being allowed, and burrs shall be carefully removed.

(*b*) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(*c*) When any finished rail shows interior defects at either end or in a drilled hole it shall be cut back to sound metal within the acceptable length of rail.

IDENTIFICATION OF RAILS.

Branding. — 19. Brands or distinguishing marks, made so plain and sharp that they may be read as long as the rails are in service, shall be rolled or stamped into side of the web of each rail in accordance with the following requirements, and to indicate :

(*a*) The name or initials of the « Manufacturer » in raised letters.

(*b*) The « Year » and « Month » of manufacture in raised figures and marks.

(*c*) The « Weight » per yard of the rail in raised figures.

(*d*) The « Type » or « Section » marked by raised letters which signify the name by which it is known, as for example :

Sections of Pennsylvania Railroad System	P.S.
Sections of American Society of Civil Engineers.	A.S.C.E.
Sections of American Railway Association	R.A.-A. R.A.-B.
Sections of American Railway Engineering Association	R.E.

(*e*) The kind of « Material », the letters, « O. H. » being used to designate « Open Hearth Steel ».

(*f*) The number of the « Melt » stamped in the web where it will not be covered by the joint bars.

(*g*) The letter indicating the « Position in the Ingot » from which the rail was rolled stamped in the web where it will not be covered by the joint bars. The top rails shall be lettered « A », and the succeeding ones « B », « C », « D », etc., consecutively; but in case of a top discard of from 20 to 35 % the letter « A » will be omitted, the top rail becoming « B ». If the top discard be greater than 35 % the letter « B » shall be omitted, the top rail becoming « C ».

Special marking. — 20. (*a*) No. 1 rails less than 33 feet long shall have both ends painted green. (Section 16.)

(*b*) The No. 1 rails of a melt which contain the highest percentage of carbon (amounting approximately to 25 % of the total number of No. 1 rails) shall be designated by the letters « H. C. » with white paint on the top surface of the head of the rail.

(*c*) Rails accepted as No. 2 rails shall have the ends painted white and shall have 2 prick-punch marks on the side of the web near the melt number, so placed as not to be covered by the joint bars. (Section 12.)

(*d*) Rails accepted as « X-rails » shall have the ends painted blue and shall have 4 prick-punch marks on the side of the web near the melt number, so placed as not to be covered by the joint bars. (Section 13.)

Classes separated. — 21. All classes of rails shall be kept separate from each other.

Loading. — 22. Rails shall be carefully handled in such manner as to avoid injuring them, and shall be loaded in cars as follows :

(*a*) No. 1 rails of each melt shall be kept together whenever possible. The « High Carbon » rails shall be loaded in separate cars also.

(*b*) No. 2 rails and « A » rails of all melts promiscuously shall be loaded in separate cars by themselves.

(*c*) « X-rails » shall be loaded in cars by themselves.

MILL PRACTICE.

Quality of manufacture. — 23. The entire process of manufacture shall be in accordance with the best current state of the art.

Ladle additions. — 24. Additions to the ladle shall be made in liquid form so far as practicable. If necessary, to make cold additions they shall be crushed to pass an inch and half screen.

Deoxidation. — 25. The steel must be well deoxidized in the furnace or ladle and the waste products eliminated before the ingots are teemed, and thus prevent minute portions of the deoxidation products from becoming entrained in the setting metal. Time is required for the deoxidation products and impurities to rise after the steel is tapped in the ladle.

Spattering. — 26. Spattering the interior sides of the molds in pricking the melts and teeming the ingots must be avoided as much as possible.

Sound ingots. — 27 (*a*) The casting of good, clean quiet setting, sound ingots, free from scales and cracks, and with reasonable flat tops without spraying with water is required.

(*b*) Ingots shall be kept in a vertical position on the ingot cars and in the soaking pits, and shall be treated in the soaking pits so as to insure thorough soaking with the subsequent increase of temperature necessary.

(*c*) Bled ingots, from the centre of which liquid steel has been permitted to escape, shall not be rolled.

(*d*) Overheated, or burned, or white sided ingots shall not be rolled.

(*e*) Ingots which have been allowed to become cold shall be re-heated in such a manner as to avoid injury to the rails subsequently rolled from them.

Discard. — 28. Sufficient discard shall be taken from the ingot to ensure freedom from injurious segregation and pipe and to secure sound rails.

Cooling. — 29. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass.

Hot-Bed Work and Straightening. — 30. (*a*) Care must be taken in cambering the rails and with the hot-bed work, so that rails will cool with a small but uniform sweep, and thereby gagging under the presses will be reduced to a minium.

(*b*) Rails while on the cooling beds shall be protected from snow, water and excessive gusts of wind.

(*c*) The supports for rails in the straightening presses shall have flat surfaces and be free from hollow places, bends or crooks, and shall be spaced not less than 60 inches.

(*d*) Rails heard to snap while being straightened shall be at once rejected.

ACCEPTANCE REQUIREMENTS.

Acceptance. — 31. In order to be accepted the rails ordered must fulfil all the requirements of the « Specifications ». If they do not do so, they will be rejected.

No. 2 rails to the extent of 5 % of the whole order will be received.

Payment. — 32. Rail accepted will be paid for according to actual weights.

Place for tests. — 33. All tests and inspection shall be made at the place of manufacture prior to shipment, except that check tests may be made at any other place selected by the purchaser without holding the manufactured articles at the mill awaiting the results of the ckeck tests, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Access to work. — 34. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made and loaded in accordance with the terms of the specifications.

Correct :	Approved :
Engineer of Standards.	*Chief Engineer.*

The questionnaire asks if certain quite local defects may not be due to objectionable treatment in manufacture (such as rails insufficiently protected against rain and snow while cooling, rails subjected to an undue amount of cold straightening, etc.), and it will be noticed that they have been guarded against in the specifications and have been a part of American specifications for many years. They answer the other questions as well in regard to prohibition of certain practices in manufacture.

It is the general opinion that rails should be manufactured under well defined specifications of the railroad companies, and under the observation of competent inspectors, as it would be a difficult matter to settle upon the actual cause of a rail failure. The rail is made to undergo service of varying conditions, and it would be a question of great delicacy in many cases to decide whether it had been punished too severely by meager maintenance, or whether the accident brought about by a broken rail should be attributed to a defect in the metal.

At one period of manufacture, it was customary for the manufacturer to guarantee his product for five years to the extent of replacement of the rail which failed, unless it was indicated by examination that it had no apparent defect and complied with the terms of the specifications, but this guaranty has long since been withdrawn on account of the rapidly increasing weights of rolling stock. The manufacturer never did share in the responsibility for a wreck due to a defective rail.

One respondent would like to have the guaranty restored, another would like to have the manufacturer held partly accountable for costs in connection with failure due to manufacture and a third considered that the specifications should fix the responsibility for an accident on the manufacturer when the failure of a rail was due to defect of the metal, provided the manufacturer did not take full precautions to avoid the defect.

CONCLUSIONS.

1. The sectional designs or profiles of rails have passed through several stages, embodying 1° on the one hand heavy and moderately wide heads and thin bases with rather low stiffness, and 2° on the other very thin and wide heads and also the extremely thin bases with maximum stiffness, to the compromise types of American Railway Engineering Association, characterized by a well balanced section with wide and moderately thick head and much heavier base with a high degree of stiffness, rather favoring the second type above.

2. The density of traffic has increased so mightily, and the concentrated weights of rolling stock have become so large, that the intensity of pressure upon the bearing surface of the rail-head and the tensile stresses inducing strains of rupture in the interior of the head of the rail have imposed conditions of service which are difficult for rails of Open-hearth carbon steel to withstand, especially as,

3. There are processes of rail manufacture at the mills imposing thermal conditions, resulting in some melts having minute shattering cracks in the interior of the rail-head, which are enlarged to final rupture of the rail in service when the character of that service is very severe.

4. Rail designs or profiles having been well proportioned physically and metallurgically, and specifications having been brought to the degree of improvement in the art considered practicable, the railroad companies with severe service conditions are upon the threshold of additional research into the materials and methods of rail manufacture which will satisfy the new demands.

B. — Rail joints.

« Most economical and efficient arrangement. »

1. — Types of joints.

Types of joints.

1. — The angle-bar type of Rail joint may be said to be used universally on the North American continent, there being only one known railroad using a plain flat fish-plate as its standard, illustrated with the drawings, the Delaware, Lackawana & Western Railroad, which adopted it only about two years ago.

The shape of the angle-bar is of many different forms, brought about by the necessity for increased strength with increased severity of service conditions, resulting in the enlarged top flange which the increased size of the rail-head made possible. It is absent from the joints for small rail sections on account of wheel-flange interference.

In some cases the base has been enlarged as well by the depending flanges between ties of the M. W. Thomson (1)

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(1) Principal assistant engineer of Pennsylvania Railroad over 30 years ago.

100 % joint, culminating in the so-called « Continuous Joint », with the flange bent flat under the base of the rail and extending its bearing over the cross-tie support, so as to grasp the base of the rail firmly. A few of the principal and heaviest types of joints are illustrated by figures 24 to 29.

The plain type of angle-bar for 105-pound rail is shown in the drawing of the three-tie centre-supported joint of the New York Central Lines (fig. 24), the only system on the continent using it, so far as known to the Reporter. It has proved to be an admirable type of joint under a heavy traffic.

The heaviest type of joint is the « Continuous » for the 136-pound rail of the Lehigh Valley Railroad (fig. 25), the heaviest weight of rail in use, except for special street locations.

The heavy angle-bar types of joints for 130-pound R. E. and 100-pound R. A.-A rails known as 100 % joints of the Rail Joint Company, as used by the Baltimore & Ohio Railroad Company, are shown by the figures 26 and 27.

The heavy angle-bar type for 130-pound P. S. rail of the Pennsylvania Railroad System is depicted by the plan, figure 28.

These are all unusually heavy and strong joints, and many similar ones are in use by a large number of administrations. These have only been selected as illustrating the different designs.

A joint which is entirely different has been introduced into use on the Delaware, Lackawanna & Western Railroad within the last two years, and is included with the illustrations (fig. 29). It consists of a pair of fish-plates supported on a channel plate extending over two ties but not fastened to the plate. The reason for the design will be discussed later on.

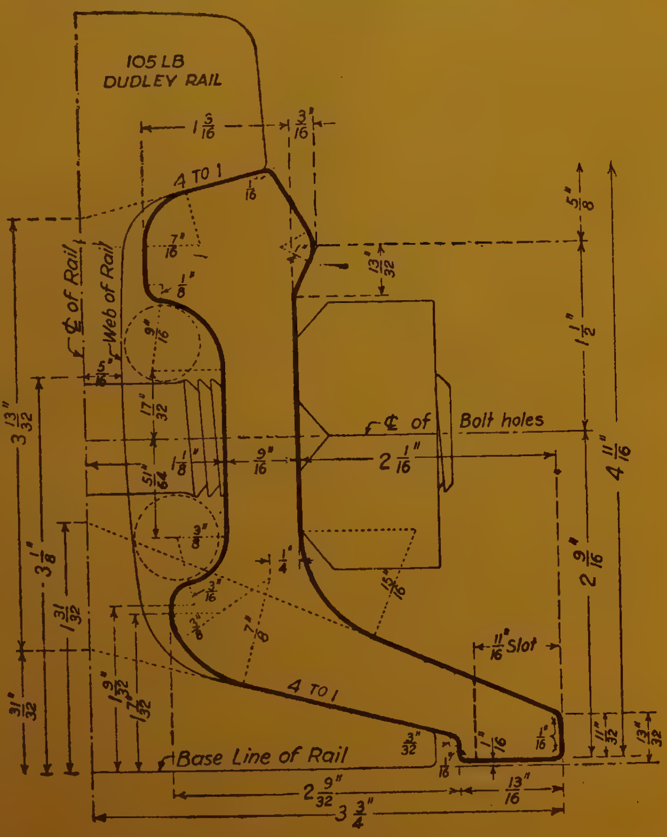
Length of rails.

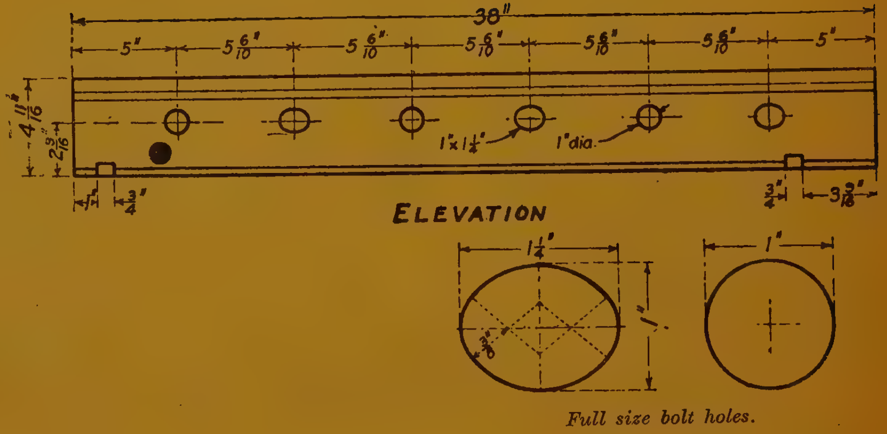
2. — The standard length of rails on the North American Continent is 33 feet, and is universally used by the railroads, except that consideration has been given intermittently to the introduction of longer lengths, and restricted amounts of rails 39 feet, 60 feet and 66 feet have been laid in the tracks at different periods.

It is customary to include in the annual rail contract a limited amount of 60 feet rails for special uses, as, laying through highway crossings in order to omit the joint, over bridges and through City streets. Twenty-five to thirty years ago, many tons of 60 feet rails were laid in the tracks of some of the principal railroad systems in order to give them a thorough trial, and some of these rails are yet in service, 20 to 25 years old. That length, however, was not regarded with sufficient favor to have been adopted as standard, although it must be admitted that the arrangements for anchoring them in order to prevent creeping were not as adequate as they might have been, and the uniform expansion gap was destroyed by crowding together of some of the rails. As such gaps were large, the rail ends became battered. Besides, an extra price of $5.00 per ton is charged by the manufacturers for such lengths.

In 1914, the Rail Committee of the American Railway Engineering Association considered the subject and recommended that its members have a considerable quantity of rails 39 feet and 45 feet long rolled in order to gain additional service information. The war interfered with the programme, but, nevertheless, several railroads have obtained and laid

Recommended by : N. Y. C. Lines, Engineering Committee.

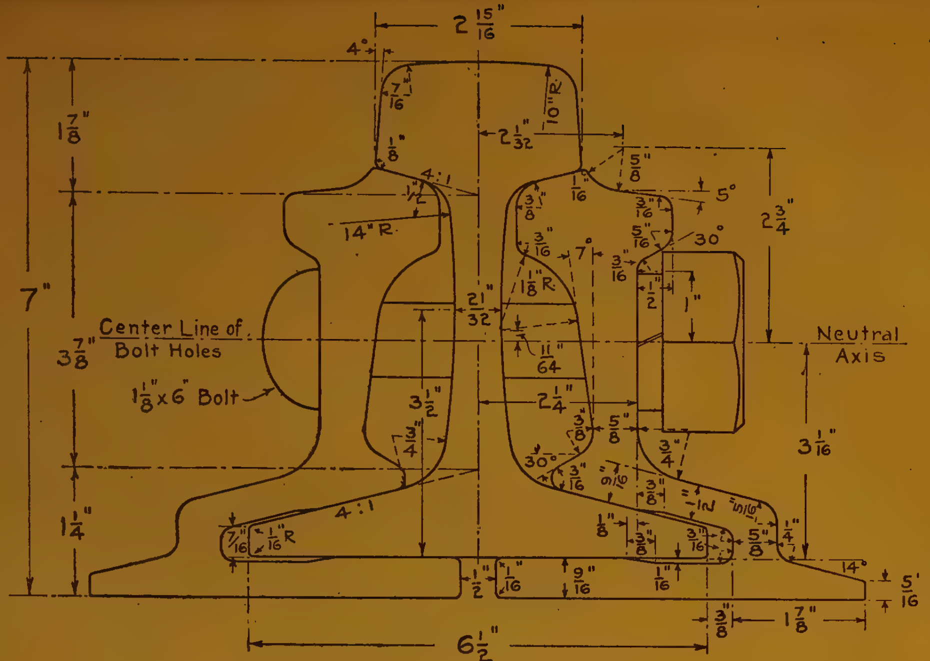


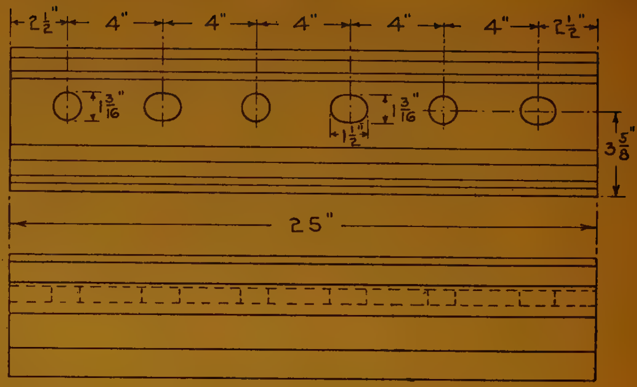


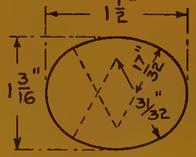
Full size bolt holes.

Area	4.54 sq. in.
Weight per pair	95.4 lb.
Neutral axis above base	2.08 inches.
Moment of inertia	9.87 in.^{4}
Section modulus-head	3.78 in.^{3}
Section modulus-base	4.74 in.^{3}

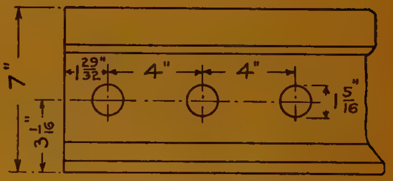
Fig. 24. — New York Central Lines. Standard splice bar for 105 lb. Dudley rail.



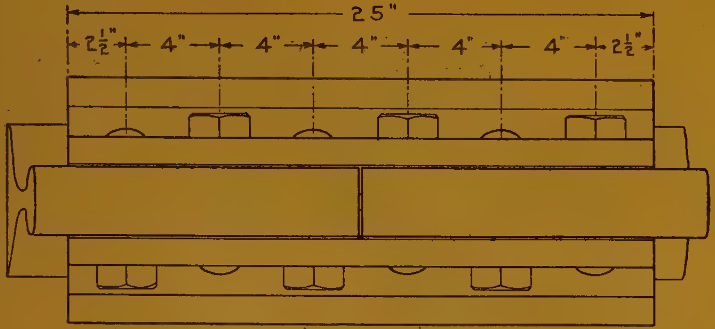




Detail of bolt hole.

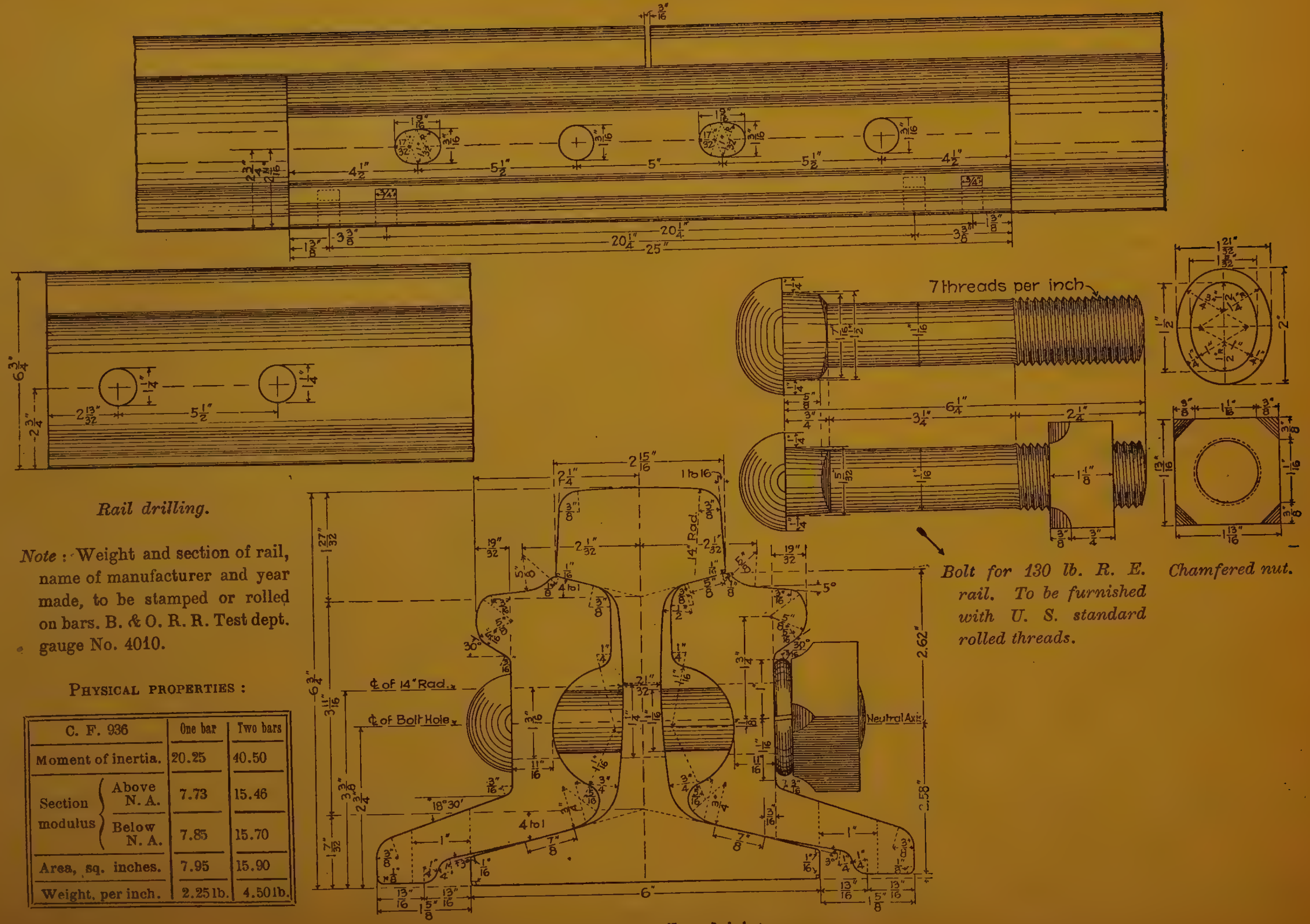


Drilling for 136 lb. rail.



Plan of joint.

Fig. 25. — Lehigh Valley Railroad.
Standard 136 lb. L. V. rail with Continuous rail joint.



Angle bar elevation.

Rail drilling.

Bolt for 130 lb. R. E. rail. To be furnished with U. S. standard rolled threads.

Chamfered nut.

130 lb. R. E. sect. rail and joint.

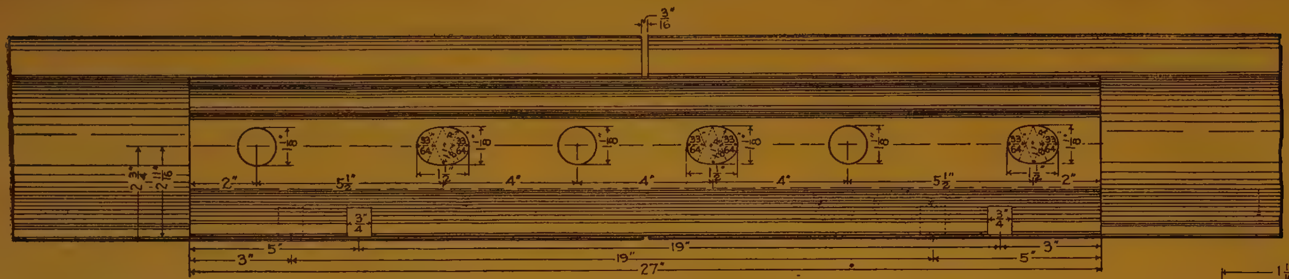
Note : Weight and section of rail, name of manufacturer and year made, to be stamped or rolled on bars. B. & O. R. R. Test dept. gauge No. 4010.

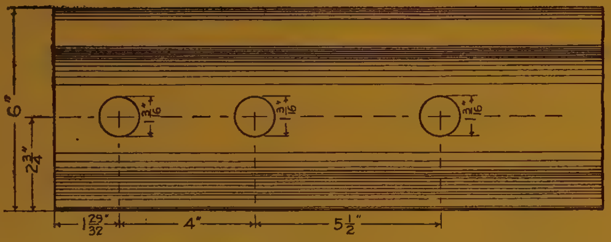
Physical properties :

C. F. 936		One bar	Two bars
Moment of inertia.		20.25	40.50
Section modulus	Above N. A.	7.73	15.46
	Below N. A.	7.85	15.70
Area, sq. inches.		7.95	15.90
Weight, per inch.		2.25 lb.	4.50 lb.

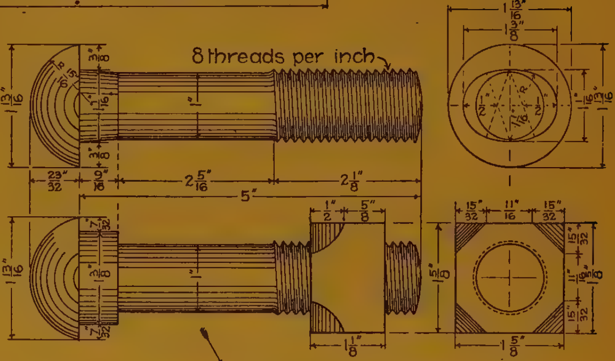
Fig. 26. — Baltimore & Ohio Railroad Four hole rail joints for 130 lb. R. E. section rail.

Angle bar elevation.





Rail drilling.

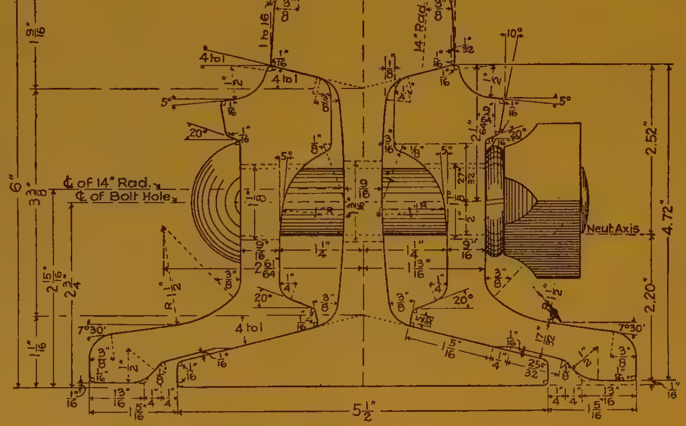


Standard Harvey grip thread bolt and chamfered nut.

Note : Weight and section of rail, name of manufacturer and year made, to be stamped or rolled on bars.

PHYSICAL PROPERTIES :

Approx. C. F. 424		One bar.	Two bars.
Moment of inertia....		11.03	22.06
Section modulus	Above N.A.	4.38	8.76
	Below N.A.	5.01	10.02
Area, square inches..		5.10	10.20
Weight per inch		1.446 lb,	2.892 lb.

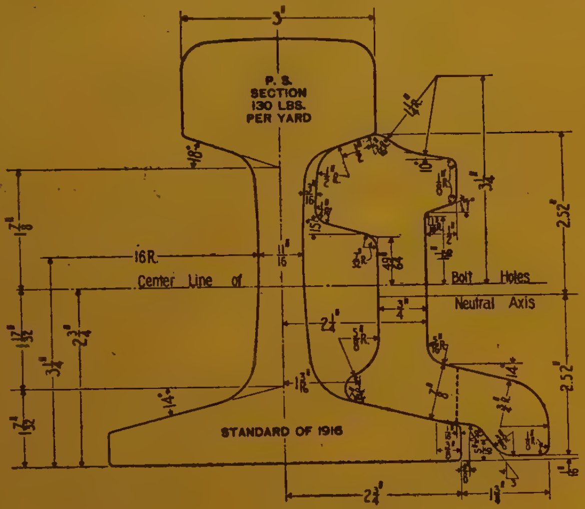


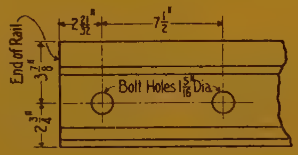
100 lb. A. R. A. section « A » rail and joint.

Fig. 27. — Baltimore & Ohio Railroad. Six hole splice bar for 100 lb. A. R. A. section « A » rail

Fig. 28. — Pennsylvania System-Standard 130 R. S. L-2 joint bar punched 7 1/2 — 5 1/2 — 7 1/2.

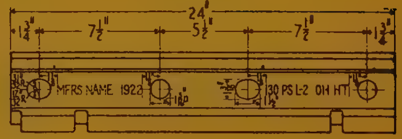
Section.

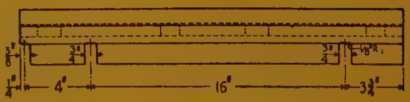




Drilling for 130 lb. P. S. rails.

Elevation.





Plan.

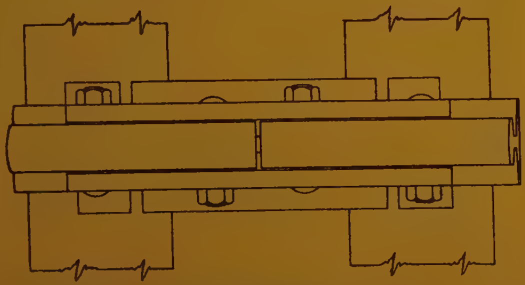
Note : All materials must conform to Pennsylvania System specifications for quenched carbon and alloy steel joint bars.

Branding must be placed in the position and kept within the limits prescribed on this plan.

Mathematical properties two, bars :

Moment of inertia	33.06
Section modulus above N. A.	13.12
— — below N. A.	13.15
Weight per inch of two bars.	3.88 lb.
Joint stiffness	45.4 %.
Area	13.68 sq. in.
Estimated weight of two bars	89 1/4 lb.

Fig. 28 (part 1).



Plan of joint.

Fig. 28 (part 2).

in the tracks several tons of 39 feet rails, as follows :

Pere Marquette	6 938 tons.
Illinois Central Railroad . . .	4 150 —
Missouri Pacific Railroad. . .	8 853 tons.
Chicago, Burlington & Quincy Railroad	16 552 —
Atchison, Topeka et Sante Fe Railway.	Unknown.

Orders for this length are no longer being placed, because the manufacturers have set a price upon them of $2.50 per ton extra, whereas they had been obtained previously without extra cost (¹).

This length of 39 feet was selected because there is now a considerable percentage of rolling stock sufficiently long to enable them to be loaded in single cars.

For the last two years, however, the Committee previously named has been studying the subject once more from all points of view in order to reach a conclusion upon the maximum length which may be considered practicable, because it is realized that the extra charge will in all probability not be eliminated except by the establishment of a standard to which all principal railroads will adhere, as considerable expense will be necessary to rearrange the plants. An extra charge cancels the greater part of the economy to be gained by the elimination of joints.

The advantage claimed for longer rail is fewer joints, resulting in a saving of joint material, labor applying and maintaining, and a better riding track. The objections to increasing the length of rail are increased space required at joints for expansion causing a greater batter at rail ends, increased number of rail anchors, increased cost of transporting and handling rail, and increased cost of rail due to changes necessary in present steel-mill operations.

The following table shows the number of joints per mile of track for various lengths of rail and the reduction in the number of joints as compared with 33 foot rail lengths.

Table 9.

—	Length of rail			
	33 feet.	39 feet.	45 feet.	50 feet.
Number of joints per mile of track . . .	320	270.8	234.6	176
Reduction in number of joints compared with 33 foot rail	—	49.2	85.4	144
Per cent of reduction compared with 33 foot rail.	—	15 %	27 %	45 %

A reduction in the number of joints is desirable. The joint being the weakest part of the track structure is the hardest to maintain. A study made several years ago on the western portion of the Pennsylvania Railroad System showed that at least one-half of all the surfacing done on track was at joints. Fewer joints will add to the riding qualities of the track. Signal circuits will be easier to maintain as less bonding will be required.

Increasing the length of rail will increase the required expansion opening. Wider space between rail ends produces

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(¹) Extra price discontinued in 1924, and large orders placed for rails 39 feet long.

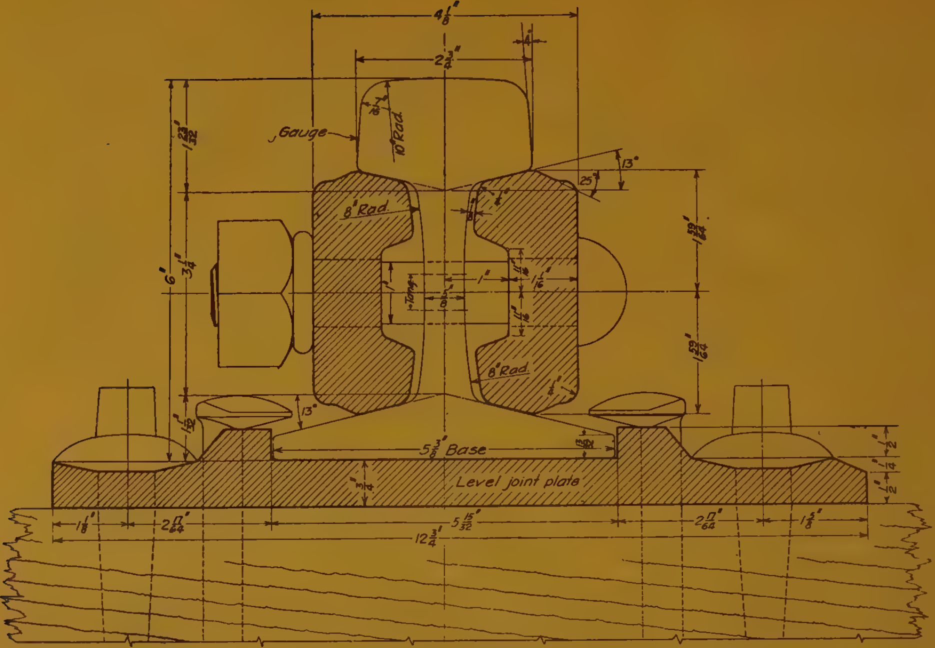


Fig. 29 (part 1). — Delaware, Lackawanna & Western Railroad. — 105 lb Neafie rail joint.

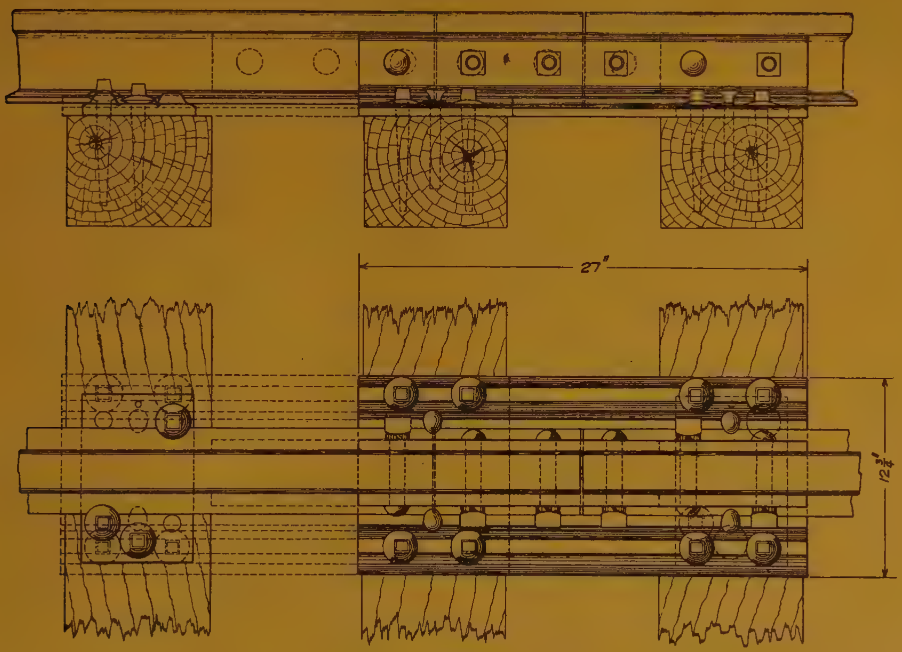
a greater blow at the joint and increases the batter at the rail ends, the wear in the contact surfaces of the joint, and the stretch in the bolts. Should not sufficient space be provided, the force of expansion will tend to kink the joints out of alignment, as was the experience with 60-foot rail tried several years ago.

The following table gives in inches the expansion space required between rail ends for a range of temperature from 25° below zero to 100° above zero, Fahrenheit, for various lengths of rails, assuming that at 100° the space between rails is closed without producing a stress in the rails.

TABLE 10.

Degree Fahrenheit.	Expansion space in inches (nearest thirty-second) for following lengths of rail			
	33 feet.	39 feet.	45 feet.	60 feet.
—25°	5/16 inch.	3/8 inch.	7/16 inch.	19/32 inch.
0	1/4 —	5/16 —	11/32 —	15/32 —
25°	3/16 —	7/32 —	1/4 —	11/32 —
50°	1/8 —	5/32 —	3/16 —	1/4 —
75°	1/16 —	1/16 —	3/32 —	1/8 —
100°	0	0	0	0

Elevation.



Plan.

Note : Dotted lines show the method of taking care of creeping rails and change in joint location on account of relaying rail.

Fig. 29 (part 2). — Delaware, Lackawanna & Western Railroad. — 105 lb Neafie rail joint.

The table shows for an extreme range of temperature of 125°, 1/16 inch more expansion space required for each six feet of additional length of rail. The spacing will not materially affects joints for a 39-foot or a 45-foot rail, but for a 60-foot rail the spacing is too much.

As the rail is anchored to the ties at each joint by spikes through the joint-bar slots, reducing the number of joints will decrease the anchorage to the ties, and additional rail-anchors will be required. On grades of heavy traffic Divisions, six rail-anchors are now being used to a 30-foot rail-length. If the length of rail be increased the number of anchors will likely be increased as follows :

TABLE 11.

Rail length.	Number of anchors, per rail length.	Number of anchors, per mile of track.	Number of additional anchors required.
33 foot.	6	1 920	...
39 —	8	2 166	246
45 —	10	2 346	426
60 —	14	2 464	544

Increasing the length of rail will increase the weight of rail-length and will add to the difficulties of handling. The following shows the weights of the various lengths of 100-pound and 130-pound rail and the increase in weight :

Table 12

Length of rail.	100-lb. per yard.		130-lb. per yard.	
	Weight of one rail	Increase in weight over 33 foot rail.	Weight of one rail.	Increase in weight over 33-foot rail.
33 feet	1 100 lb.	—	1 430 lb.	...
39 —	1 300 —	200 lb.	1 690 —	250 lb.
45 —	1 500 —	400 —	1 950 —	520 —
60 —	2 000 —	900 —	2 600 —	1 170 —

Rail is usually handled by mechanical appliances except in replacement of defective rail. Most of our rail-loading machines can handle 60-foot rails and the cost of handling by machines will be increased but little. In replacing a 33-foot 130-pound defective rail, eight men are usually required, and, as our track gangs in winter are limited to four or five men, it now requires two gangs to replace a rail. A 39-foot rail is about the limit that can be handled even by two such gangs. For 45-foot rails, it would be necessary to maintain larger gangs.

The present standard length, 33 feet, was determined largely by the lengths of cars available for transporting rail. Since this length was adopted longer cars have become more common. From an analysis of the Equipment Register for December 1922, gondola cars owned by the Pennsylvania Railroad System may be classified as follows :

Table 13.

Inside length of car.	Number of gondola cars.	Percentage of total numbers of gondola cars.
Less than 34 feet.	1 754	2.4 %
34 ft. to less tan 39 ft. 6 in.	43 434	59.0 %
39 ft. 6 in. to less than 45 ft. 6 in.	23 894	32.5 %
45 ft. 6 in. or greater	4 524	6.1 %
Total. . .	73 603	100.0 %

39 % of our gondola equipment will handle rails 39 feet in length without using two cars, but only 6 % will handle 45-foot rails in single loads. Shipping rail in double loads is objectionable, as more cars are required. The cost of the extra car, although not reflected in additional charges to rail adds to the operating expense. Assuming that the extra car, with an operating cost of $7.00 per day, will be required fifteen days in transporting 50 tons of rail, the additional cost will be $2.10 per ton of rail for 45-foot and 60-foot lengths.

The steel mills are designed for rolling 33-foot rails, and any increase in length will require remodelling the mills. The Carnegie Steel Company estimates the cost of remodelling the Edgar Thompson mills for rolling 39-foot rail at 1 million dollars. Rolling rails longer than 33 feet in the mills as now designed decreases the tonnage production and adds to the operating costs of the mill. The Steel Companies ask a premium of $5.00 per ton for rail rolled 60 feet long and longer. If a longer length should become generally used this additional charge will likely be lowered or omitted. Longer rails will require less sawing and drilling, but there will be a reduction in out-put on account of a larger tonnage being refused due to surface imperfections.

The table 14 is an estimated difference in cost of using longer rail length for 1 mile of track 130-pound rail as compared with using 33-foot rail lengths.

As long as the Steel Companies insist on an extra charge of $5.00 per ton, the use of rail longer than 33 feet is not economical. Disregarding the extra charge, a small saving may be made, the larger saving being for the longer rail. Sixty-foot rail requires too much expansion space and is too heavy to be conveniently handled. Fourty-five foot rail is also too heavy for our present track gangs, the expansion space required is not excessive but an extra car is required for transporting and the benefits to be derived from the use of 45-foot rail do not warrant the expense of the extra car. Rail 39 feet in length can be handled by our present methods. The number of cars on which 39-foot rail can be loaded is now of sufficient proportion to normally secure an ample car supply for transporting in single loads. The increased space required for expansion is so small as to be immaterial.

The two lengths most favored at present are either 39 feet or 45 feet, but the question has not yet been placed before the American Railway Engineering Association for decision; it is yet in Committee. The preponderance of opinion of those answering the questionnaire is in favor of 39 feet, but nearly as many recommend the present length of 33 feet. Only a few have spoken in favor of 45 feet, or 66 feet (1).

Staggered joints.

3. — It is the universal practice of North American railways to lay tracks with alternating joints, and they have never looked with favor upon tracks laid with joints opposite one another. The Grand Trunk Railway was built with even joints, as in English practice, and was maintained in that way for many years, up to 1897, since which time all rail has been laid with broken or staggered joints. It is now a part of the Canadian National Railways.

It is believed in this country that alternating joints provide stronger and better riding track at less expense. On curves, joints directly opposite one another favor kinks in the line.

Relationship of joint with ties.

4. — There are three plans of arrangement of the joints with reference to the joint ties in use :

(*a*) Suspended,
(*b*) Supported,
(*c*) Hit or miss.

---

(1) Very recently the Southern Pacific Company (April, 1924), purchased 131 245 tons of rail of 110-pound R. E. section, all in 39 feet lengths, with the usual allowance of 10 % of shorts, down to 24 feet.

TABLE 14.

ITEM.	PRICE.		39 foot rail. 270.8 joints, per mile.		45 foot rail. 234.6 joints, per mile.		60 foot rail. 176.0 joints, per mile.	
			Savings.	Extra cost.	Savings.	Extra cost.	Savings.	Extra cost.
		Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
4 hole L2 joints	Joint material	3.00						
Including bonding	Applying	0.25						
39 foot rail 49.2 less	Bonding	0.65	192					
45 foot rail 85.4 less	Total	3.90	...	...	333			
60 foot rail 144 less	...		..	...	...	...	562	
Rail anchors	Material	0.25						
39 foot rail 246 more	Applying	0.04	...	71				
45 foot rail 426 more	Total	0.29	...	...	...	124		
60 foot rail 544 more	...		...	...	...	...	...	158
Labor handling	...		...	10	...	20	...	30
Additional cost of rail : $5.00 per ton	...		...	1 020	...	1 020	...	1 020
Total	...		192	1 101	333	1 164	562	1 208
Net difference	...		...	909	...	831	...	646
Difference omitting premium charge of $5.00 per ton for rail	...		111	...	189	...	374	
Difference omitting premium charge but including cost of additional car for transporting 45 foot and 60 foot rail : $2.10 per ton			111	...	...	239	...	54
Savings in maintenance at $0.75 per joint per year for an average life of rail of eight years			295	...	512	...	864	
Total savings for eight years including first cost but omitting the premium charge for longer rail			406	...	273	...	810	

The first is the plan generally in use, because, it is argued, it distributes the load over a larger area. This is undoubtedly the case, if the alternate meant by « supported joint » is on one tie which would be necessary with a short joint-bar, but, with a longer joint-bar, the same argument for supported joint as above is applicable, and that is the claim of the only railroad, the New York Central Lines, using it. The joint-bars of that System are 36 inches long, recently lengthened to 38 inches (fig. 24), extending symmetrically over 3 ties with the rail ends upon the center tie, thus affording a greater bearing area, being on 3 ties, than is the case with the joint suspended on 2 ties. That System claims further that it « cuts down deflection and prevents cutting out of the rail at the receiving end ».

The third, or « hit or miss » plan, has been used by some companies during the last ten years upon the claim of greater economy in track maintenance, while keeping it at the same time in prime condition for fast and heavy traffic. The rail is laid without any attempt at adjustment of the joint ties to fit the position of the joint, which may by chance come as a suspended or a supported joint, or may take any position that is intermediate with them. The economy is claimed by reason of not having to replace the ties when the rail is laid new, and, consequently, should come only once in the life-time of the rail, which may be from five years, under very heavy traffic, to twenty-five years, under light traffic, making the claim for economy not particularly well supported in many cases. No specific comparative records of cost have been furnished by any one.

It has been well set forth by many that the saving claimed is apt to be more theoretical than actual, especially when the materials are all shipped before hand so that the work can be carried on systematically and in order, *i. e.*, laying a moderate amount of rail, spacing the ties, making the usual renewals at the same time, giving the track a slight lift, lining and surfacing it and filling it in with fresh ballast; the work resulting in economically prepared track of good, ship-shape appearence, with the joints properly set with reference to the ties.

The requirement that ties shall always be spaced so as to obtain uniformity, either with suspended or supported joints, insures the rehabilitation of the track following the laying of the new rail. The absence of such requirement encourages the neglect of this work which is so necessary to good maintenance. It may result in inferior track maintenance and lack of precision and workmanlike appearence in the track structure.

It is when the materials are not on hand at the proper time that some of the work must be done over, resulting in increased cost and destruction of rail and ties by lack of the necessary work at the right time.

There is a very large mileage where the traffic is moderate and the rail lasts all the way from eight to twenty years before re-laying is necessary, and, consequently, after the track has been well put up with properly spaced joints, the necessity for re-laying rail does not come for many years. A possible saving in such cases is much reduced.

There are other lines where the traffic is extremely heavy and the topography bad, so that frequent rail renewals are required, and in these cases there might be opportunity for saving in rail laying and track maintenance which may be considerably offset by the appearance, and the amount of which will be exceedingly difficult to prove, provided the materials are assembled early and in proper order for the work.

In answer to the last part of this question, unsymmetrical spacing of the joints to the sleepers, no objection could be raised by the advocates of non-adjustment of joint ties to fit the joint, but the general practice of such adjustment for a suspended joint does not favor the suggestion.

This subject is really continued in the next query.

Anchoring joints.

5. — This review is closely related to the previous one, and is a continuation of it. The problem is of dual nature, some considering one part of the most importance, and others the second part. These two separate and distinct questions are :

(*a*) The question of non-slot-spiking the joint to the ties so as to relieve the joint ties of the stress due to creeping rail;

(*b*) The question whether it is better practice to have a joint adjusted to the ties, which may or may not be spiked, or to adopt the « hit or miss » idea of letting the joint come where it may, in which case spiking is necessarily omitted.

The question of spiking or non-spiking, (*a*), stands by itself, for it is agreed to by everyone that if non-spiking in slots is practiced, it will be necessary to replace their resisting reaction against creeping of the rail by the use of a sufficient number of rail anchors.

But, it has been the wish of maintenance men for a long while to equip the track with a sufficient number of rail anchors to prevent creeping. If they are allowed by the managing officers to do this under a plan of non-spiking in slots, then there is no good reason why the same plan cannot be carried out with slot-spiking, and with precisely the same effect, for if there is the requisite number of anchors in each case there will be no undue stress and movement at the joint under either practice.

Consequently, the question of non-slot-spiking the joint in order to relieve it from the duty of holding the rail against creeping falls to the ground. It can be relieved by the use of rail anchors under either plan of maintenance. Many of the engineers replying consider that it is important to keep the ties adjusted to the joint, but have not made it clear that this can be done without the necessity of non-slot-spiking the bars. Indeed, the relationship is best and most accurately preserved by this spiking.

Those who consider the practice of relieving the joint ties from the stress due to rail creeping as predominant and desirable do not have to let the question of slot-spiking or non-slot-spiking enter into consideration, for the use of an adequate number of rail anchors will satisfy the condition.

If, however, the position of the joint with reference to the ties is regarded as immaterial, then question (*a*) becomes unimportant, for slot-spiking must be abandoned.

Those who consider (*a*) as the most important have no use for consideration of (*b*), while those who consider (*b*) as predominant must ignore the slot-spiking of (*a*) but must use the requisite number of rail anchors.

Many, it will be observed, do not wish to give up (*a*), but desire additional data relative to the prospective economy in the use of practice (*b*), the « hit or miss » method of laying rail.

No one seems to have any accurate cost data concerning the practice of non-adjustment of the ties to the joints, though several estimates, differing widely have been made. These are due to the different conditions under which different estimators assume that the work will be done.

It is assumed by some that there will be a large saving in labor cost in connection with laying rail, but if all materials are assembled beforehand for the Spring work as they should be, and if the work of rail laying, renewal of ties, spacing the ties evenly in connection with surfacing and ballast renewals when heavy, and lining, with ballast renewals to dress up when light, be done in sequence and in an orderly manner, it will be pretty difficult to tell how much of the cost belongs to the adjustment of joint ties to the joints. This saving, if any, may or may not be offset by the cost of extra appliances, as rail anchors, according tó the view taken. If a sufficient number of rail anchors is used to prevent the rail from creeping, without assistance from the joint in any case, as many believe is the correct plan, then there may be no additional cost on that account.

Nevertheless, it is the general opinion of railway engineers that by spiking the joint to the ties additional work is imposed upon the weak place in the track, forgetting that a fixed position of the rail prevents such stress, the fixed position being obtained by the use of the same number of rail anchors as may be necessary under the plan of non-spiking at the joints. The practice does not correspond with the views of many, but the new joint of the Delaware, Lackawanna & Western Railroad, figure 29, previously referred to, was designed in accordance with the principle of relieving the joint of « extra work », as it is expressed.

Keyed joints.

6. — Thirty-five years ago, the frogs which had been extensively constructed with wedges or keys instead of bolts had ceased to give satisfaction in service, and were being replaced with the bolted type as rapidly as possible. The reasons which led to the abolition of the keyed frog hold good for the keyed rail joints, and with still greater force today than at that time, for the load imposed upon the clamp portion is now so much greater that it is difficult to make the clamps sufficiently strong to resist it. The same dissatisfaction has arisen with the clamps used for fastening guard rails to the traffic rail, which, in spite of their enormous size at the present time, together with heat-treatment of the material, are no longer able to hold the guard rail in place effectively. Hence they, too, are being abandoned for the one-piece manganese guard rails.

We do not, therefore, consider that a keyed rail joint would be satisfactory in spite of the advantage to be derived by the omission of the holes in the rail ends, thereby lessening the risk of breakage owing to such holes.

Wheel-carrying joints.

7. — Quite extensive trials of the Barschall rail joint were made twenty-seven years ago by the Pennsylvania Railroad System with unfavorable results. The outside bar was extended vertically upward to the surface level of the rail, with the object of assisting to carry the wheel over the rail expansion gap, but the design was not considered satisfactory for these reasons :

(*a*) All wheel-treads are not worn alike, and some will take bearing on the supporting bar while others will not;

(*b*) In the case of wheel-treads quite considerably worn, the bearing on the outside bar was such as to lift the wheel slightly from its bearing on the rail, causing « jumping »;

(*c*) It is believed that unsymmetrical bars lead to twisting of the joint, thereby causing difficulty in maintaining good rail line;

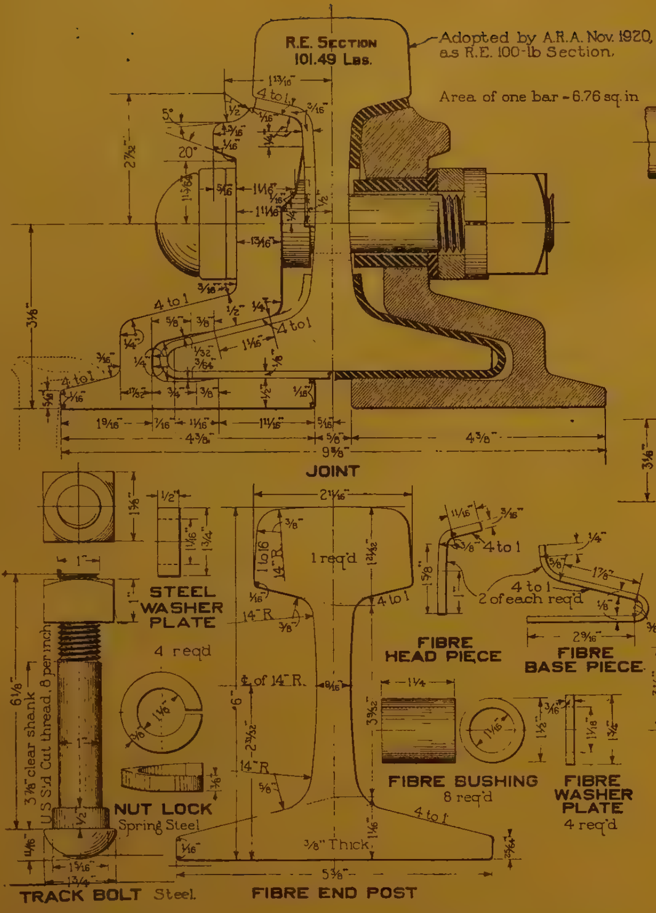


Fig. 30 (part 2). — Union Pacific System. Common Standard insulated Continuous joint. — C S 100 lb. rail.

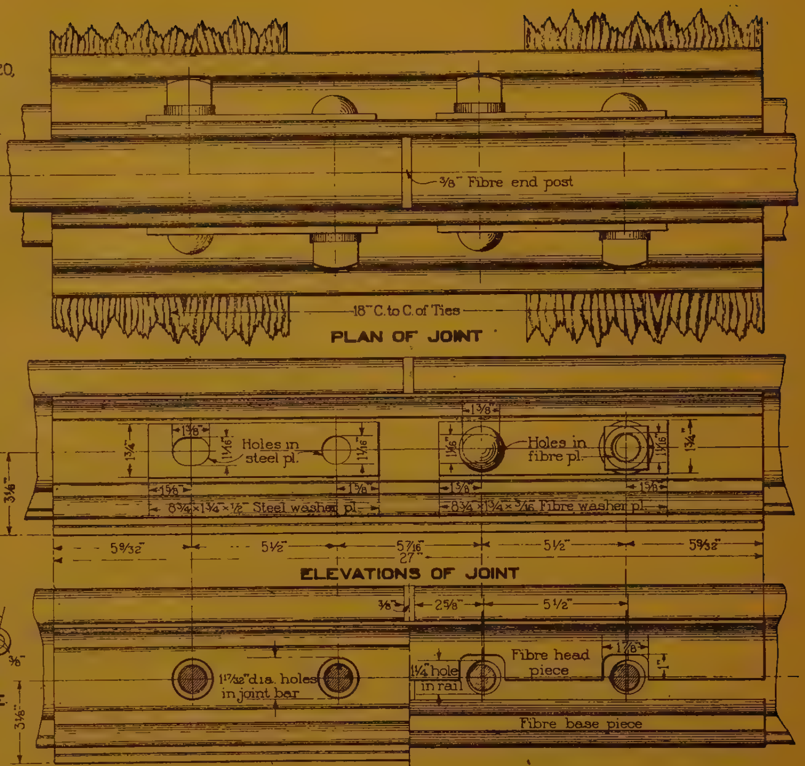


Fig. 30 (part 1).

Table of weights.

No.	Item.	Wt. each.	Total.
2	Joint bars	47.80 lb.	95.60 lb.
4	Bolts and nuts.	2.125 lb.	8.50 lb.
4	Nut locks	0.1875 lb.	0.750 lb.
4	Steel washer plates	1.875 lb.	7.50 lb.
Total weight of metal in joint 112.350 lb.			

(*d*) There was always apprehension by the Operating officers that some unusually careless laborer might reverse the bars when applying them, and derail a train with the tall bar on the gauge side of the rail.

Lapped or rebated rail-ends.

8. — Practically the only kind of lapped rail-ends tried in this country was obtained by mitering the ends to an angle of 45°. Such rails were tried quite extensively twenty-nine years ago, but were considered unsatisfactory for two reasons principally :

(*a*) When not held rigidly from creeping, the expansion gap became either too wide or too close, in the first case allowing the pointed rail ends to become battered down from lack of effective support, and

(*b*) In the second, forcing the rail ends apart by further creeping which left a dangerous lip when on the outside rail of a curve, with the lip on the gauge side toward the traffic. Sometimes rails were crowded up together in this way with such force as to wedge off the bolts.

Fishing angle.

9. — The angle of inclination of the fishing surfaces adopted by the American Railway Engineering Association is 14°, or 1 : 4.

Too small an angle favors short life of the joint bars, because, as they become abraded in service they are pulled in by the bolts until they are against the web of the rail, in which position they have ceased to be effective.

If the angle be too large, great stress is put upon the bolts, causing them to stretch or be ruptured.

An angle of 18°, or 1 : 3.08, has been used in the design of 130-pound P. S. rail, and 13°, or 1 : 4.33, for the A. S. C. E. sections and the special designs of several other railroads.

The Bangor & Aroostook Railroad has an angle of 24° 54′, or 1 : 2.15, which is quite unusual.

Length of joint-bars.

10. — The early joint bars were short and with four bolts, but in the eighteen hundred and nineties were largely replaced by longer bars with six holes. During the first ten years of the new century, the short four-hole joint, with heavier bolts, began to regain favor, and may now be considered as the standard type of the United States and Canada, although the six-hole joint bars are still the standard of some companies.

The four-hole bars are from 24 to 27 inches long, the longer length being preferable, as the 24 inch bar requires the joint ties to be too close together for good tamping in order to be seated rightly upon them.

The six-hole bars are from 25 to 28 inches long for joints suspended on two ties, and 38 inches long for the three-tie centre-supported joint of the New York Central Lines, the only system making use of that type (fig. 24). The latter were 36 inches long up to the present year, allowing a space of only 5 inches for tamping between the joint ties.

Planing rail surfaces.

11. — With the slight variations in heights of rail, it has never been deemed necessary to plane off the rolling surface of rails in order to have them precisely at the same level.

Joint-plate wear.

12. — When, owing to wear of the contact surfaces, fish-plates no longer retain a good hold of the joint, it has been the practice to replace them with new joints, provided they have not lasted as long as the life of the rail, which is usually the case with rail lasting from five to eight years, but may or may not be so with the rail lasting considerably longer. In the latter case, where the traffic is rather heavy, there may be a second set of joint bars put on during the life of the rail.

It has never been customary :

(*a*) To use fish-plates with increased height (to compensate for the wear of the fishing surfaces of the rail ends);

(*b*) To place narrow metal strips of suitable shape between the fishing surfaces of rails and plates to stop the existing play;

(*c*) To displace eccentrically in a trailing or facing direction the two fish-plates of the joint which, with this object, are made with six-holes instead of four, although only four of the holes are utilized for bolts at the same time.

To a considerable extent, joint bars are reclaimed by re-forging so as to restore their dimensions between the fishing surfaces. This practice is not economical unless there is a reasonably constant supply of such bars in order to provide regularity of work, unless it can be varied by repair work of other kinds. Making dies for a large miscellaneous assortment of bars is costly.

Insulated joint.

13. — The types of insulated joints used almost universally in North America are the :

Continuous, figure 30;
Weber, figure 31;
Keystone, figure 32.

The above are patented devices, but in some cases the ordinary non-patented angle bars planed away to provide space for the insulating fibre are used.

II. — Freedom for expansion of rails.

Bolt-hole allowances.

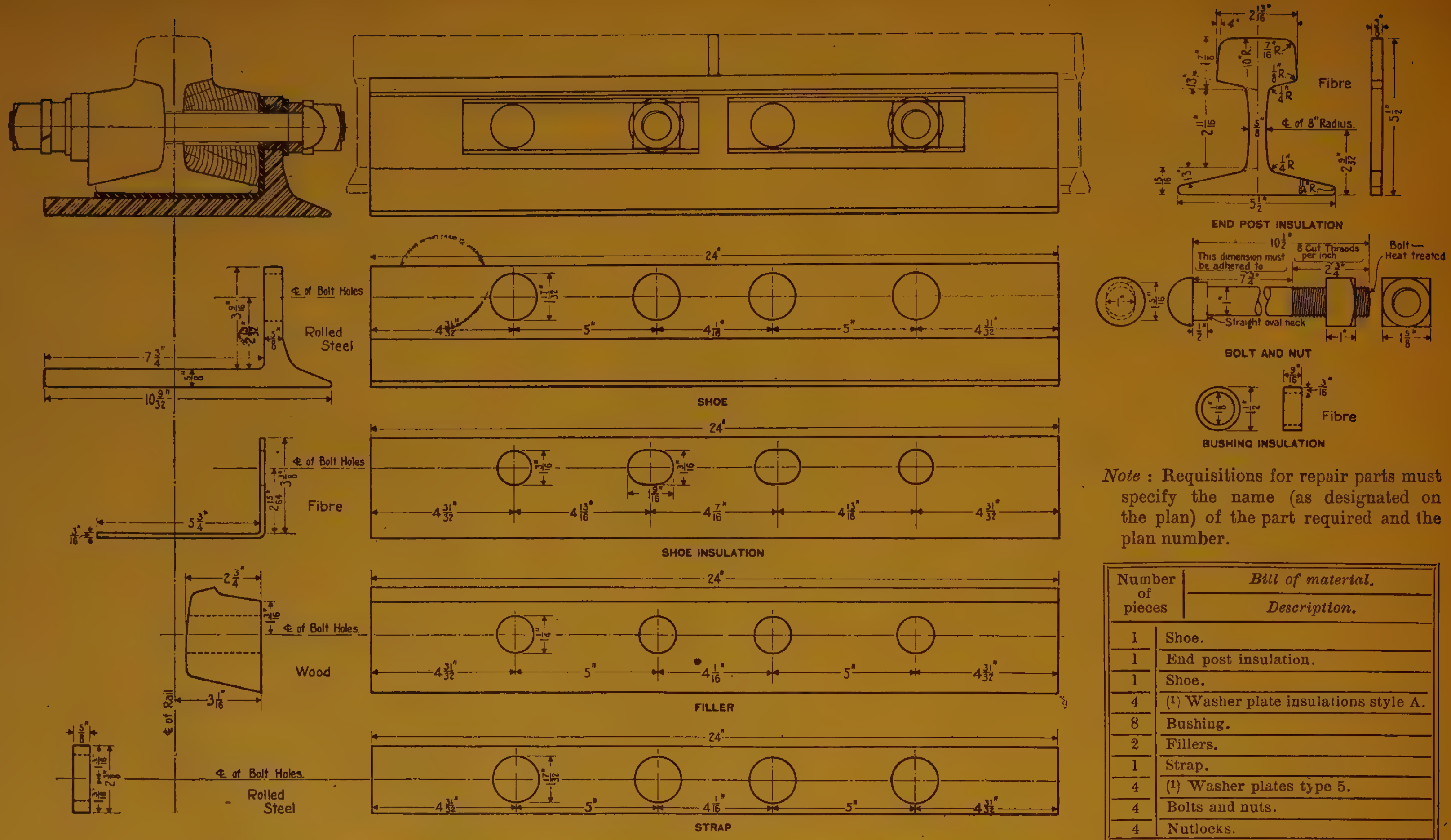
1. — (*a*) The practice in allowing for a maximum calculated gap between the ends of rails, 33 feet long, to provide for expansion, leaving out of account tolerances and variations in the manufacture, is not uniform, but may be considered to be in general about 3/16 inch, although it is as small as 1/8 inch with some roads, and as large as 7/16 inch with others, all of the intermediate sixteenths being also used.

(*b*) When tolerances and variations in manufacture are taken into account, in addition to the calculated provision, the amount allowed is generally about 3/8 inch, with differences in practice as low as 1/8 inch and as high as 11/16 inch.

(*c*) The least possible gap at the joint, the ends of the two adjacent rails being drawn away as far from one another as practicable, is taken, commonly, as « 0 », although some roads consider it as much as 1/4 inch.

Expansion allowance.

2 and 3. — Expansion-shims of metal of the proper thickness, in accordance with standard plan, shall be placed between the ends of adjacent rails in order to insure the space-allowance for expansion required by the rail temperatures in the following table, and shall be left in



Note : Requisitions for repair parts must specify the name (as designated on the plan) of the part required and the plan number.

Number of pieces	*Bill of material.* *Description.*
1	Shoe.
1	End post insulation.
1	Shoe.
4	(1) Washer plate insulations style A.
8	Bushing.
2	Fillers.
1	Strap.
4	(1) Washer plates type 5.
4	Bolts and nuts.
4	Nutlocks.

(1) Washer plate insulation style A, and washer plate type 5, as shown in detail on plan of repair parts for continuous insulating joint for 100 lb. P. S. rails drilled 2 21/32 — 5 1/2 — 2 13/32 — 4 1/2 — 1 29/32 — 5 and 2 29/32 — 6.

Fig. 31. — Pennsylvania Railroad System Standard Weber insulating joint for 100 lb. P. R. R. rails drilled 1 29/32 5 6.

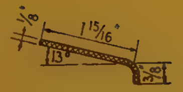
Fig. 32.

NORTHERN PACIFIC RAILWAY.

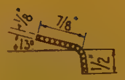
KEYSTONE INSULATED RAIL JOINT

FOR

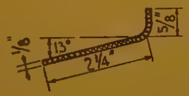
STANDARD 100, 90, 85 AND 72 LB. RAIL.



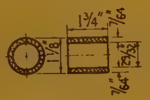
Top Fiber Plate-Outside-F.
(For all Rail Sections.)



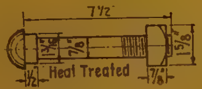
Top Fiber Plate Gauge Side-E.
(For all Rail Sections.)



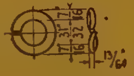
Bottom Fibre Plate D.
(For all Rail Sections.)



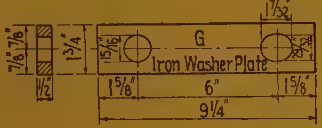
Fiber Bushing J.

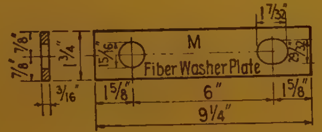


7/8" × 7 1/2" Button Head Bolt I
U. S. Standard Cut.
Threads to be full and clean.



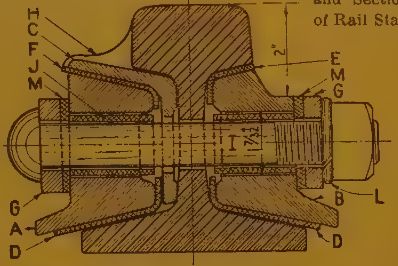
Improved Hipower Nut Lock L.



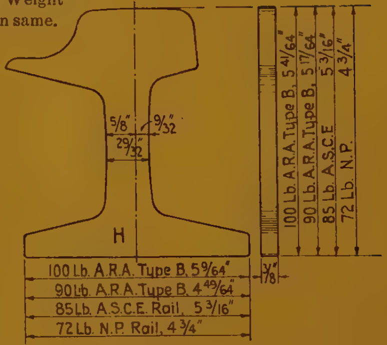


Number of Parts Required for One Joint.		
A	Splice Bar—Outside	1
B	Splice Bar—Gauge side	1
C	Filler - Metal I R. H—I R H.	2
D	Bottom Fiber Plate	2
E	Top Fiber Plate, Gauge side	1
F	Top Fiber Plate, Outside	1
J	Fiber Bushing	8
H	Fiber End Post 3/8" thick	1
I	7/8" Button Head Bolt and Nut	4
M	Fiber Washer Plate	4
G	Iron Washer Plate	4
L	Improved Hipower Nut Lock	4

Note: All fiber to be coated with Parafin and Section and Weight of Rail Stamped on same.

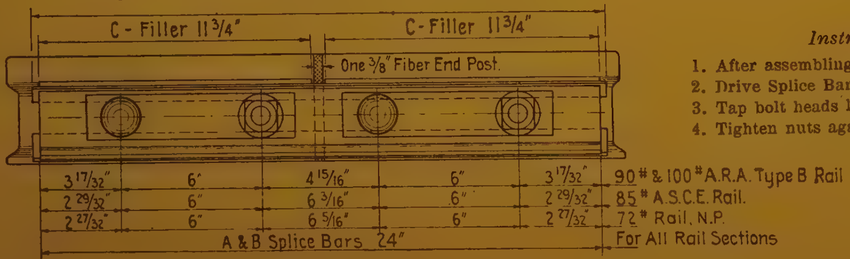


Note: Pieces « A », « B », « C », to be Steel Stenciled showing weight of rail


5/8"
9/32"
29/32"
H
100 Lb. A.R.A. Type B. 5 9/64"
90 Lb. A.R.A. Type B. 4 49/64"
85 Lb. A.S.C.E. Rail, 5 3/16"
72 Lb. N.P. Rail, 4 3/4"
3/8"
100 Lb. A.R.A. Type B, 5 41/64"
90 Lb. A.R.A. Type B, 5 17/64"
85 Lb. A.S.C.E. 5 3/16"
72 Lb. N.P. 4 3/4"

Fiber end post.

Length of top and bottom fiber plate 24 1/2".



Dimensions shown are Center of Holes in Splice Bars and Fillers, Not Center of Holes in Rails.

Instructions for Applying Joints.

1. After assembling tighten nuts uniformly, beginning at middle of joint.
2. Drive Splice Bars on both sides of rail and tighten nuts again.
3. Tap bolt heads lightly with spike maul and tighten nuts again.
4. Tighten nuts again in three or four days and again in ten days.

place long enough to prevent disturbance from laying of rails in advance (table 15).

TABLE 15

—

Expansion-allowance table.

Rail temperature (Fahrenheit).	Openings between rail ends.
For 33-foot rails :	
Below 25° above zero.	1/4 inch.
From 25° above zero to 50° above.	3/16 —
— 50° — — 75° —	1/8 —
— 75° — — 100° —	1/16 —
For 60 foot rails :	
Below 25° above zero.	7/16 inch.
From 25° above zero to 37° above.	3/8 —
— 37° — — 50° —	5/16 —
— 50° — — 62° —	1/4 —
— 62° — — 75° —	3/16 —
— 75° — — 87° —	1/8 —
— 87° — — 100° —	1/16 —

With temperature over 100°, rails shall be laid close together without bumping.

In tunnels, where the temperature is above 70°, the rails should be laid close together without bumping. When the temperature is below 70° a space of 1/16 inch for each 25° variation shall be left between the ends of 33-foot rails.

The space between the rails at insulated joints should be 1/2 inch, using end posts as shown on standard plan.

When laying new rails, the standard rail-thermometer shall be used for ascertaining the temperatures by which the openings between rail ends in the Expansion Allowance Table are fixed. The thermometer shall be laid out of the sun on the base of the rail next to the web in advance of the laying and left there long enough to record the temperature accurately. Expansion shims should be issued to the men laying rail by the man taking the temperature readings, who as the temperature changes beyond the limits fixed in the table, will take up the shims in use and issue others.

All thermometers should be checked by the Supervisor to see that they are accurate.

The above is the practice recommended by the American Railway Engineering Association, with some additional details of instruction, and is quite generally used by the companies. In some cases, the atmospheric temperature is taken instead of that of the rail.

Joint lubrication.

4. — Some companies oil the joints twice a year with a heavy oil, one mixture being 1 gallon of car oil to 7 gallons of fuel oil, sprayed by means of an air pump and hose from a supply carried in a tank.

III. — Quality of metal in fish-plates.

Specifications.

1 and 2. — The Joint bars in use in North America are now made of Open-hearth steel exclusively, unless, indeed, some Bessemer steel bars might be used in quite low-traffic service.

The angle-bar joints for the heavy traffic of the important lines are heat-treated, but there are also angle-bar joints for lesser service which are of high carbon steel not heat-treated.

There are also proprietary joints of patented design which are not heat-treated, the claim being made that the form of design furnishes the required strength.

Specifications for « Quenched Carbon and Alloy Steel Joint Bars », and for « High Carbon Steel Joint Bars », are submitted. (Exhibits 5 and 6.)

Special steel.

3. — The details of heat-treatment are left to the decision of the manufacturer. Alloys of different kinds may be introduced in order to produce a material which will conform with the specifications. These alloys, as mechanical mixtures, would not serve the purpose.

4. — With the modern design of heavy and strong joint made of steel in accordance with the specifications quoted, the breakages are very few, and it is not considered necessary by the majority of the companies to keep records.

IV. — First cost of installing and maintaining joints.

First cost.

1. — The information given by the respondent companies in the matter of first cost of a pair of joints, a joint for each rail, has not been sufficiently exact, nor in sufficient numbers, to be of value in comparison. One could not tell always if all items had been included. Moreover, the difference in design is considerable.

Maintenance.

2. — The result is much the same in dealing with the cost of maintenance. One company reported the cost of maintenance per single joint at 20 cents and another at 56 to 59 cents.

EXHIBIT 5.

KEYSTONE RAILROAD SYSTEM.

Specifications for quenched carbon and alloy joint bars.

(21 June 1921.)

APPLIANCES OR ARTICLES.

Plans. — 1. The joint bars shall be made in accordance with the standard designs of the Keystone Railroad System.

Material. — 2. The material for the joint bars shall be of steel manufactured by the Basic Open-Hearth process, or shall be an acceptable alloy steel.

CHEMICAL REQUIREMENTS.

Chemical composition. — 3. The chemical composition of the joint bars manufactured from each melt of steel, determined as described in section 4, shall be within the following limits :

Carbon	Minimum percentage	0.35
	Maximum percentage	0.60
Phosphorus ...	Maximum percentage	0.04

Note. — In the event of nickel and chromium being present to the extent of approximately 1.00 % and 0.35 % respectively, these elements together will be considered as the equivalent of 0.07 % of carbon in the above requirements.

Analyses. — 4. The manufacturer shall furnish the inspectors with analyses and information in accordance with the following requirements :

(*a*) For each melt of Open-hearth steel, chemical analyses, from a test ingot made during the pouring of the melt, of the elements carbon, phosphorus, manganese, sulphur, and the other principal elements, such as nickel and chromium, if an alloy steel, used to attain the physical properties specified in section 5.

(*b*) Drillings for analyses shall be taken not less than 1/8 inch beneath the surface of the test ingot.

(*c*) The purchaser may arrange for analyses to be made from finished joint bars representing each melt, and the phosphorus content thus determined shall not exceed the requirements specified in section 3 by more than 25 %. Drillings for the analyses may be taken from a finished bar at any point midway between the center and the surface of the solid bar, or turnings may be taken from the test specimen.

PHYSICAL REQUIREMENTS.

Mechanical strength and ductility. — 5. The steel used for making the joint bars must be capable of sustaining :

	Carbon steel.	Alloy steel
(*a*) A minimum « Tensile Strength » in pounds per square inch of	100 000	110 000
(*b*) A minimum « Yield Point » in pounds per square inch of	70 000	85 000

(*c*) A minimum « Elongation » percentage, measured in 2 inches of $\frac{1\,600\,000}{\text{Tensile strength}}$, but in no case under 10.

(*d*) A minimum « Reduction of Area » percentage at point of fracture of $\frac{3\,500\,000}{\text{Tensile strength}}$, but in no case under 25.

(*e*) If the test be made on the finished joint bar, « Cold Bending » of the quenched bar without sign of fracture on the outside of the bent portion, through 45° around an arc, the diameter of which is three times the thickness of the test specimen.

(*f*) If the test be made on a specimen cut from the finished joint bar, « Cold Bending » of the specimen without sign of cracking on the outside of the bent portion through 90° around an arc, the diameter of which is three times the thickness of the test specimen.

Physical qualities. — 6. Tests shall be made to determine the :

(*a*) Mechanical strength.

(*b*) Ductility or toughness as opposed to brittleness.

Kinds of tests used. — 7. The physical qualities shall be determined by :

(*a*) The Tension Test to find the Yield Point, the Tensile Strength or Ultimate Breaking Stress, the Elongation percentage, and the percentage of Reduction of Area.

(*b*) The Cold Bend Test.

Method of testing. — 8. (*a*) The « Tension Test » shall be conducted in accordance with the Standard Methods for Testing, Serial Designation E 1-18 of the American Society for Testing Materials, except where difference occurs herein.

(*b*) The « Yield Point » is the load per unit of original cross-section at which a marked increase in the deformation of the test piece occurs without increase of load, and shall be determined by the drop of the beam of the testing machine or by the use of dividers.

(*c*) When making the tension test, the cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the value of 0.25 inch per minute for yield point, and 1 inch per minute for tensile strength be exceeded, the speed being increased after passing the yield point.

Test specimens. — 9. (*a*) The tension test pieces shall be taken from the finished joint bars after final treatment. They shall be cut so that the sides of the pieces are parallel to the direction in which the bar has been rolled.

(*b*) The test pieces for tension tests shall be in the form of round rods, with the central 2-1/4 inch length turned to a 1/2 inch diameter, and with the ends threaded or unthreaded to fit into the holders of the testing machine, in accordance with the standard form and dimensions for tension test pieces of the American Society for Testing Materials.

(*c*) The cold bend test specimens shall be finished joint bars after final treatment, or

(*d*) If desired by the purchaser, bend test specimens may be square or rectangular in section, in which case they shall not be less than 1/2 inch in width between the planed sides, and shall have two parallel faces as rolled.

Temperature of test pieces. — 10. The temperature of the test pieces shall be between 15°6 and 43°3 C. (60° and 110° F.).

Proportion of tests. — 11. The process of heat treatment may be either by quenching successive charges, or by the continuous method of quenching which is carried on mechanically and continuously.

(*a*) When the process of treatment is quenching by « successive charges », one tension and one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and one bend test shall be made from each melt, which has not been tested as part of some other unit.

(*b*) When the process of treatment is « continuous », one tension and one bend test shall be made from not less than 1 000 bars. If more than one melt is represented in 1 000 bars, one tension and one bend test shall be made from each melt, which has not been tested as part of some other unit.

(*c*) Bars shall be piled separately, in accordance with each quenching charge of melt, until tested and accepted by the inspector, and shall have marked thereon designating characters so as to be readily identified for inspection.

(*d*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*e*) If the percentage of elongation of any tension test specimen is less than that specified in section 5 (*c*) and any part of the fracture is more than 3/4 inch from the center of the gauge length as indicated by scribe scratches marked on the specimen before testing, one retest shall be allowed.

Reheat treatment. — 12. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may reheat treat such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in section 11.

ACCURACY OF MANUFACTURE.

Section. — 13. The joint bars shall be smoothly rolled and the section shall conform as accurately as possible to the template furnished by the purchaser. The edges and bearing surfaces shall be well and accurately defined.

Length. — 14. The joint bars shall be cut to the standard length prescribed by the purchaser, and shall not vary therefrom more than 1/8 inch.

Punching, etc. — 15. (*a*) All punching, slotting and shapings of joint bars shall be done before treatment at a temperature of not less than 750° C. (1 382° F.).

(*b*) All the bolt holes shall be punched before treatment in one operation from the outside of the bar, without bulging or distorting the section, and the lower flange shall be slotted for spikes in accordance with the standard drawing, the slotting being done in one operation. A variation of 1/32 inch in the size and 1/16 inch in the location of holes will be allowed.

Finish. — 16. When finished, the bars shall be straight, without camber in either plane, and with the outside surface of the web parallel to the axis of the rail. They shall be free from kinks in any direction, and free from burrs, cracks and injurious mechanical defects. There must be no sharp up-turned corner on either end, creating an opportunity for cutting in and nicking the bearing surface of the rail on the under side of the head.

IDENTIFICATION OF APPLIANCES OR ARTICLES.

Branding. — 17. Brands or distinguishing marks shall be rolled or pressed into the outside of the bar, and a portion of this marking shall appear on each finished joint bar, in accordance with the following requirements, and to indicate :

(*a*) The name or initials of the « Manufacturer ».

(*b*) The « Year » of manufacture.

(*c*) The kind of « Material », the letters « O.H. » being used to designate « Open-Hearth Steel ».

(*d*) The « Heat Treatment », by the letters « H.T. ».

(*e*) The number or characteristic for « Design ».

(*f*) All brands or marking shall be done so effectively that the marks may be read as long as the joint bars are in service.

Separate classes. — 18. The rolled joint bars from each melt shall be piled separately until tested and accepted by the inspector.

MILL PRACTICE.

Soundness. — 19. The steel shall be homogeneous, and, when broken, show a uniformly sound and characteristic fracture.

20. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

21. The joint bars shall enter the quenching medium, oil or water, at a temperature not less than 750° C. (1 382° F.).

ACCEPTANCE REQUIREMENTS.

Acceptance. — 22. In order to be accepted, the material or articles ordered must fulfil all the requirements of the « Specifications ». If they do not do so, they will be rejected.

Defect found after delivery. — 23. Joint bars which show objectionable defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who must pay the freight charges both ways.

Place for tests. — 24. All tests and inspection shall be made at the place of manufacture prior to shipment, except that check tests may be made at any other place selected by the purchaser without holding the manufactured articles at the mill awaiting the results of the check tests, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Access to works. — 25. Inspectors representing the purchaser shall have free entry to the works of the manufacturers at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the joint bars are furnished in accordance with the terms of these specifications.

Correct :	Approved :
Engineer of Standards.	*Chief Engineer.*

EXHIBIT 6.

KEYSTONE RAILROAD SYSTEM.

Specifications for high carbon steel joint bars.

(*14 June 1921.*)

ARTICLES OR APPLIANCES.

Plans. — 1. The joint bars shall be made in accordance with the standard designs of the Keystone Railroad System.

Material. — 2. The material for the joint bars shall be of steel manufactured by the Basic Open-Hearth process.

CHEMICAL REQUIREMENTS.

Chemical composition. — 3. The chemical composition of the joint bars manufactured from each melt of steel, determined as described in section 4, shall be within the following limits :

Carbon-minimum percentage . . .	0.45
Phosphorus-maximum percentage.	0.04

Note. — In the event of nickel and chromium being present to the extent approximately of 1.00 % and 0.35 % respectively, these elements together will be considered as the equivalent of 0.07 % of carbon in the above requirements.

Analyses. — 4. The manufacturer shall furnish the inspectors with analyses and information in accordance with the following requirements :

(*a*) For each melt of Open-hearth steel, chemical analyses, from a test ingot made during the pouring of the melt, of the elements carbon, phosphorus, manganese, sulphur, and the other principal elements, such as nickel and chromium, used to attain the physical properties specified in section 5.

(*b*) Drillings for analyses shall be taken not less than 1/8 inch beneath the surface of the test ingot.

(*c*) The purchaser may arrange for analyses to be made from finished joint bars representing each melt, and the phosphorus content thus determined shall not exceed the requirements specified in section 3 by more than 25 %. Drillings for the analyses may be taken from a finished bar at any point midway between the center and the surface of the solid bar, or turnings may be taken from the test specimen.

PHYSICAL REQUIREMENTS.

Mechanical strength and ductility. — 5. The steel used for making the joint bars must be capable of sustaining :

(*a*) A minimum « Tensile Strength », in pounds per square inch of 85 000

(*b*) A minimum « Yield Point », in pounds per square inch of. 45 000

(*c*) A minimum « Elongation » percentage, measured in 2 inches of $\frac{1\,500\,000}{\text{Tensile strength}}$, but in no case under 14.

(*d*) A minimum « Reduction of Area » percentage at point of fracture of $\frac{2\,300\,000}{\text{Tensile strength}}$, but in no case under 25.

(*e*) If the test be made on the finished joint bar, « Cold Bending » of the bar without sign of cracking on the outside of the bent portion through 45° around an arc, the diameter of which is three times the thickness of the test specimen.

(*f*) If the test be made on a specimen cut from the finished joint bar, « Cold Bending » of the specimen without sign of cracking on the outside of the bent portion through 90° around an arc, the diameter of which is three times the thickness of the test specimen.

Physical qualities. — 6. Tests shall be made to determine the :

(*a*) Mechanical strength.

(*b*) Ductility or toughness as opposed to brittleness.

Kinds of tests used. — 7. The physical qualities shall be determined by :

(*a*) The Tension Test to find the Yield Point, the Tensile Strength or Ultimate Breaking Stress, the Elongation percentage, and the percentage of Reduction of Area.

(*b*) The Cold Bend Test.

Method of testing. — 8. (*a*) The « Tension Test » shall be conducted in accordance with the Standard Methods for Testing, Serial Designation E 1-18 of the American Society for Testing Materials, except where differences occur herein.

(*b*) The « Yield Point » is the load per unit of original cross-section at which a marked increase in the deformation of the test piece occurs without increase of load, and shall be determined by the drop of the beam of the testing machine, or by the use of dividers.

(*c*) When making the tension test, the cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the values of 0.25 inch per minute for yield point, and 1.0 inch per minute for tensile strength be exceeded, the speed being increased after passing the yield point.

Test specimens. — 9. (*a*) The tension test pieces shall be taken from the finished joint bars after final heating. They shall be cut so that the sides of the pieces are parallel to the direction in which the bar has been rolled.

(*b*) The test pieces for tension tests shall be in the form of round rods, with the central 2-1/4 inch length turned to a 1/2 inch diameter, and with the ends threaded or unthreaded to fit into the holders of the testing machine, in accordance with the standard form and dimensions for tension test pieces of the American Society for Testing Materials.

(*c*) The cold bend test specimens shall be finished joint bars, or

(*d*) If desired by the purchaser, bend test specimens may be square or rectangular in section, in which case they shall not be less than 1/2 inch in width between the planed sides, and shall have two parallel faces as rolled.

Temperature of test pieces. — 10. The temperature of the test pieces shall be between 15°6 and 43°3 C. (60° and 110° F.).

Proportion of tests. — 11. (*a*) Tension and bend tests shall be made of the test pieces selected by the inspector from each melt, one for each test, and both tension and bend tests must pass the requirements for acceptance.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in section 5 (*c*) and any part of the fracture is more than 3/4 inch from the center of the gauge length as indicated by scribe scratches marked on the specimen before testing, one retest shall be allowed.

ACCURACY OF MANUFACTURE.

Section. — 12. The joint bars shall be smoothly rolled and the section shall conform as accurately as possible to the template furnished by the purchaser. The edges and bearing surfaces shall be well and accurately defined.

Length. — 13. The joint bars shall be cut to the standard lengths prescribed by the purchaser, and shall not vary therefrom more than 1/8 inch.

Punching, etc. — 14. (*a*) All punchings, slotting and shaping of joint bars shall be done at a temperature of not less than 750° C. (1 382° F.).

(*b*) All the bolt holes shall be punched in one operation from the outside of the bar, without bulging or distorting the section, and the lower flange shall be slotted for spikes in accordance with the standard drawings, the slotting being done in one operation. A variation of 1/32 inch in the size and 1/16 inch in the location of holes will be allowed.

Finish. — 15. When finished, the bars shall be straight, without camber in either plane, and with the outside surface of the web parallel to the axis of the rail. They shall be free from kinks in any direction, and free from burrs, cracks and injurious mechanical defects. There must be no sharp up-turned corner on either end, creating an opportunity for cutting in and nicking the bearing surface of the rail on the under side of the head.

IDENTIFICATION OF APPLIANCES OR ARTICLES.

Branding. — 16. Brands or distinguishing marks shall be rolled or pressed into the outside of the bar, and a portion of this marking shall appear on each finished joint bar, in accordance with the following requirements, and to indicate :

(*a*) The name or initials of the « Manufacturer ».

(*b*) The « Year » of manufacture.

(*c*) The kind of « Material », the letters « O.H. » being used to designate « Open-Hearth Steel ».

(*d*) The number or characteristic for « Design ».

(*e*) All brands or marking shall be done so effectively that the marks may be read as long as the joint bars are in service.

Separate classes — 17. The rolled joint bars from each melt shall be piled separately until tested and accepted by the inspector.

MILL PRACTICE.

Soundness. — 18. The steel shall be homogeneous, and, when broken in tension, show a uniformly sound and characteristic fracture.

Discard. — 19. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

ACCEPTANCE REQUIREMENTS.

Acceptance. — 20. In order to be accepted, the materials and articles ordered must fulfil all the requirements of the « Specifications ». If they do not do so, they will be rejected.

Defect found after delivery. — 21. Joint bars which show objectionable defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who must pay the freight charges both ways.

Place for tests. — 22. All tests and inspection shall be made at the place of manufacture prior to shipment, except that check tests may be made at any other place selected by the purchaser without holding the manufactured articles at the mill awaiting the results of the check tests, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Access to works. — 23. Inspectors representing the purchaser shall have free entry to the works of the manufacturers at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the joint bars are furnished in accordance with the terms of these specifications.

Correct :	Approved :
Engineer of Standards.	*Chief Engineer.*

Life.

3. — The life of the joint has been given for the most part as the life of the rail, which is estimated from eight to fifteen years generally, but sometimes to twenty years. However, this rail, having served its limited time in important main tracks, is then transferred to less important main tracks and yard and side tracks, after which the rail, joints, and bolts are sold for scrap. In some few instances, the joints are reconditioned, but the majority of the companies answering « no ».

Spring washers.

4. — Spring washers for track bolts are commonly used by the administrations in North America. They are principally of the coiled spring type, which are of two qualities according to their strength, the High Spring Pressure and the Low Spring Pressure, which are explained in the specifications quoted. (Table 21.)

There is also a type of rectangular shape, crimped in order to act as a spring, and embracing two bolts, which is made of spring steel material.

The so-called Harvey grip-thread nut is used by a number of lines, sometimes without a coiled spring washer. The true Harvey grip-thread was an under-cut thread on a cut-thread bolt, whereas that now so designated is a rolled thread not under-cut, and is not of equal value with the original design.

Prolonging life.

5. — It is quite common practice to oil joints with a heavy asphaltic-base oil, which assists in prolonging the life of joint bars and their accessories, and, in addition, the oil-quenching in the heat-treatment process for joint bars and bolts adds to their rust-resisting properties.

CONCLUSIONS.

1. — The strength and stiffness of joint bars have been improved to a large degree :

(*a*) By the improvement in the design;

(*b*) By the employment of Open-hearth instead of Bessemer steel in the manufacture;

(*c*) By the heat-treatment of the steel, either with or without additional alloys.

2. — By the use of heat-treated material, the joint strength has been brought to a close approximation of that of the rail-section itself.

3. — These improvements above cited have reduced joint breakages to an almost negligible quantity.

EXHIBIT 7.

KEYSTONE RAILROAD SYSTEM.

Specifications for coiled spring washers.

(1) *High spring pressure and*
(2) *Low spring pressure.*

APPLIANCES OR ARTICLES.

Scope. — 1. These specifications prescribe the chemical and physical properties intended for the material of the spring washers purchased, and state in detail the methods of testing for proving their fulfilment. They cover two classes of coiled spring washers, one of High Spring pressure and one of Low Spring Pressure. The Purchaser's order will state which kind is required.

Plans. — 2. Spring washers shall be made in accordance with the standard sizes, dimensions and forms of the Keystone Railroad System. In general, they will meet the following requirements :

(*a*) Circular form.
(*b*) Parallel type.

Material. — 3. The material for coiled spring washers shall be of a carbon steel or an acceptable alloy steel manufactured by the Basic or Acid Open-Hearth Process, the Electric Furnace Process or the Crucible Process.

CHEMICAL REQUIREMENTS.

Chemical composition. — 4. The chemical composition of the spring washers manufactured from each melt of steel shall be within the following limits :

Phosphorus : Not to exceed 0.05 %.
Sulphur : Not to exceed 0.04 %.

PHYSICAL REQUIREMENTS.

Mechanical values. — 5. The finished spring washers must be capable of sustaining :

	1° High spring pressure.		2° Low spring pressure.	
	For diameter of bolt, in inches.	Pounds.	For diameter of bolt, in inches.	Pounds.
(*a*) A minimum « Spring Pressure » in pounds when compressed to 0.01 inch spring height solid of	13/16	7 000	13/16	1 000
	7/8	7 000	7/8	1 000
	1	8 000	1	1 500
	1-1/8	10 000	1-1/8	2 000
	1-1/4	12 000	1-1/4	...

(*b*) A minimum « Elastic Strength » measured by a reaction of 0.25 inch, remaining after the finished spring washer has been subjected for a period of 1 hour to pressure sufficient to compress it flat and has been released.

(*c*) « Twisting » to 45° without sign of fracture one end of the finished spring washer while at the same time the other end is held securely in a vise. When further twisted until broken, the structure at the fracture must be of fine grain, homogeneous, and of uniformly silky structure.

(*d*) A « hardness » of between 400 and 475, Brinell scale.

Physical qualities. — 6. Tests shall be made to determine :

(*a*) Spring pressure.
(*b*) Elastic strength.
(*c*) Hardness.

Methods of testing. — 7. (*a*) The « Spring Pressure » shall be determined on a standard tensile test machine arranged for compression by compressing the test sample at increment loads of 100-lb., measuring the deflection at each load to an accuracy of not less than 0.001 inch. The pressure at the spring height of 0.01 inch within solid shall be determined from the graph made by means of the load and deflection readings. The pressure determined in this manner shall not be less than that specified.

(*b*) The « Elastic Strength » shall be determined by compressing and twisting the test pieces.

(*c*) The « Hardness » shall be determined by the Brinell method, using a 10 millimetre ball and 3 000 kilogram weight.

Test specimens. — 8. (*a*) The test pieces shall consist of finished spring washers taken from the proposed shipment.

(*b*) The temperature of the test pieces at the time of testing shall be between 15°6 and 43°3 C. (60° and 110° F.).

Description and proposition of tests. — 9. (*a*) Tests shall be made of specimens selected by the Inspector at random from lots of not over 15 000 pieces of finished product offered for acceptance. Two specimens shall be selected for each test (pressure, elastic strength, twisting and hardness), and, if both meet the requirements of the specifications, the lot will be accepted. If one of the specimens fails, a third piece shall be selected and tested, and, if it meets the requirements of the specifications, the lot will be accepted. If, however, the third piece fails, the lot will be rejected.

(*b*) The above is the usual method of procedure in testing, but in any event, a sufficient number of tests shall be made to satisfy the Inspector that the spring washers, meet the specifications in every respect.

(*c*) When required, the manufacturer shall furnish samples of spring washers from a preliminary lot before proceeding with the fulfilment of the order, and give sufficient notice in advance of the date when they will be ready for inspection.

Re-heat-Treatment. — 10. (*a*) If the results of the physical tests do not conform to the requirements specified, the manufacturer may re-heat-treat each lot, but not more than three additional times, unless authorized by the purchaser, and re-test shall be made as specified in section 9.

(*b*) No lot which has failed to pass the tests shall be offered for further test until after the spring washers in the lot have been re-heat-treated.

ACCURACY OF MANUFACTURE.

Size of stock. — 11. Uniformity in size of steel stock used for making coiled spring washers and the dimensions around which the spiral is coiled are desirable. In general, the sizes and position of coil shall be as stated below, and if a manufacturer desires to furnish nut locks of different arrangements and made from other sizes of steel stock the consent of the purchaser must be obtained.

Size of bolt diameter.	Dimension of outside diameter of spring washer.	Approximate width of spring washer on side adjacent to nut.	Thickness of spring washer in coiling position.
1-1/4 inches.	2-5/16 inches.	7/16 inch.	5/16 inch.
1-1/8 —	2-1/16 —	7/16 —	5/16 —
1 inch.	1-13/16 —	3/8 —	5/16 —
7/8 inch.	1-11/16 —	3/8 —	1/4 —
13/16 inch.	1-11/16 —	3/8 —	1/4 —

Tolerance. — 12. The weight of finished spring washers per thousand lot shall be at least 97 per centum of the theoretical weight, the weight of a cubic inch of steel being taken as 0.2833-lb.

Finish. — 13. All finished pieces must be clean, smooth, without burrs or rough edges, of uniform size, with well shaped symmetrical coil and cross section free from injurious mechanical defects, and be finished in a first-class workmanlike manner.

IDENTIFICATION. — SHIPMENT.

Packing. — 14. The finished spring washers shall be packed in quantities of 1 000-1 500 in securely hooped kegs or well fastened boxes. Containers shall be left open until the inspection is completed.

Branding. — 15. Identification will be by the manufacturer's marks on the containers which shall be :

(*a*) Name of manufacturer.

(*b*) Class (high spring pressure or low spring pressure).

(*c*) Size of spring washers (inside diameter, width and thickness).

(*d*) Number of spring washers.

MILL PRACTICE.

Heat-treatment. — 16. (*a*). The scientific accuracy of the heat-treatment according to the best methods known for securing uniformity of temper of the highest efficiency attainable shall be guaranteed by the manufacturer.

(*b*) Tempering or draw back treatment of the spring washers after quenching will be necessary in order to relieve the quenching stresses.

ACCEPTANCE REQUIREMENTS.

Acceptance. — 17. In order to be accepted, the coiled spring washers ordered must fulfil all the requirements of the « Specifications ». If they do not do so, they will be rejected.

Defect found after delivery. — 18. Spring washers to the extent of 5 % or more of the order which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who must pay the freight charges both ways, and replace the defective spring washers with new ones fulfilling the requirements of the specifications.

Place of tests. — 19. All tests and inspection shall be made at the place of manufacture prior to shipment, except that check test may be made at any other place selected by the purchaser without holding the manufactured articles at the mill awaiting the results of the check tests, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Access to works. — 20 Inspectors representing the purchaser shall have free entry to the works of the manufacturers at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the spring washers are furnished in accordance with the terms of these specifications.

Correct :	Approved :
Engineer of Standards.	*Chief Engineer.*

ADDENDA

For South America, replies were received from :

1° The Buenos-Ayres Great Southern Railway Company, Limited;

2° Ferro Carril Central Argentino;

3° Nitrate Railways, Chili.

A. — Broken rails.

The Tee-rail used in European countries is used in South America, and the general practices in track construction and maintenance have been introduced from there quite largely, though somewhat influenced by North American details.

1. — Rail breakage records are kept, but the breakages are not numerous, being about 50 per anum for a main line mileage of 6 760.9 km. (4 201 miles) for road 1, and 3 626 miles for road 2.

The business is considerable, being 14 500 000 train miles (passenger and freight) for No. 1, and 10 700 000 for No. 2.

For the first, the maximum axle loads for locomotives are 19 tons on a wheel base of 2 m. 34 (7 ft. 8 in.), and the speeds 90 km. (56 miles) over the 100-pound rail on stone ballast, and 75 km. (46.5 miles) when the ballast is black earth.

2. — The breakages are found for the most part close to the joint, taking the form in one road of a splitting of the web horizontally through the bolt holes. Another type of fracture is through the lower flange, frequently started by a diminution of metal due to saltpetre in earth ballast or to the kick of spike upon the foot. Breaks show a crystalline structure denoting hardness. Road No. 2 considers that 75 % of the breakages since 1919 have been in rails rolled between the year 1885 and 1890.

3. — The extent of rail-wear allowed before removal to inferior service is generally about the same as in North America.

Rails are laid with an inclination from the surface-plane of the sleeper of 1 in 20.

One road thinks the breakages occur more frequently on rising than falling grade, while the other does not consider they are affected one way or the other.

Sleepers are spaced 17 per 40-foot rail length, but in some cases are increased in number to strengthen the track on inferior ballast.

They have not found work on the track at various temperatures to have any effect on the rails, but fish-plates have frequently broken when lifting track in cold weather.

It is believed that the bolt holes influence breakages, but it is not known to what extent.

70 % of the breakages occur within 1 m. (3 ft. 3 in.) of the end of the rail, 20 % within 2 m. (6 ft. 6 in.), and 10 % in other parts, in the case of road No. 2.

The track is laid with suspended joint.

4. — Piping is rarely noticed.

5. — High silicon rail has not shown any marked superiority over the ordinary standard, but rolled manganese

for important junctions and crossings have given excellent results.

6. — Provided the rails comply with the standard specification, both in chemical composition and in the tests, they think the rest lies with themselves. If the circumstances are otherwise, they are of the opinion that the responsibility should be shared by the manufacturer, and this as a rule is their custom.

B. — Rail joints.

1. — Types of joints.

1. — The angle bar type of joint is used, suspended on two ties which are spaced for heavy rail, centre to centre, 20 to 23 inches.

2. — The length of rail is 40 feet, and it would not be advantageous to increase it owing to extra care required in handling a greater length to obviate bending and undue stress whilst loading, unloading and laying in the track, and to avoid increasing number of men in permanent way gangs.

3. — The joints have been placed opposite each other on tangent track, and staggered on curves where greater lateral resistance is desirable, but road 2 has found that alternating joints make a much better running track requiring less maintenance, and that change is being made when carrying out renewals and ballasting with shell or stone ballast, though no change is being made where the ballast is earth.

4. — « Suspended joints give a smoother running and elastic track with the loads better distributed than with a supported joint, which induces battering of the rail ends and alters the stresses of the fishplates. »

As traffic generally runs in both directions, no difference can be made in the distance of facing or trailing sleepers from the joint.

5. — « Fishplates being of less strength than the rails they join, it is not advisable to put further stresses upon them, beyond slotting the flanges to receive the heads of the dog-spikes which greatly assist in preventing rail creep, both rail and sleeper being securely fixed together.

« It is economical and will give fair results to use the joint for the purpose of dealing with rail creep, but it is far from being entirely satisfactory. »

Rail creep has been almost prevented by covering the rail to the underside of the head with ballast.

6. — The wedge and keyed joints have not been tried.

7. — The plan of raising the outer fishplate to the rolling surface of the rail has been tried, but not adopted, probably because of extra expense and difficulty in making.

8. — The square-end rails are considered best.

9. — The road with a fishing-angle of 20° considers that experience has proved it to be a good angle.

The road with 24-1/2° is inclined to think it should be changed to something between 14° and 20°, as it would be less liable to twist.

10. — A six-bolt joint is used, 30 inches long in one case, and 33 in the other.

The preference of one is strong for the 6-bolt joint, and the other indifferent.

11. — The slight irregularities of level between the rolling surface of two rails does not warrant any special treatment.

12. — The road with 20° fishing-angle uses metal liners to repair worn fishplates with satisfactory results, but the road with the high fishing-angle does not find them necessary. The other expedients are not considered desirable.

13. — Fibre insulating-joints are used.

II. — **Freedom of expansion of rails.**

1. — (*a*) The maximum calculated gap between rails is 11 mm. (7/16 inch);
(*b*) The greatest possible gap is 5/16 to 3/8 inch.;
(*c*) Nil is minimum space.

2. — Rail expansion allowances are :

—	Ballast to top of sleeper.	Ballast to top of sleeper.
Hot weather.	1 mm.	2 mm.
Warm weather	2 mm.	3-1/2 mm.
Medium weather	3 mm. (1/8 inch bare).	5 mm. (3/16 inch full).
Cold weather	4 mm.	6-1/2 mm.
Freezing weather	5 mm. (3/16 inch full).	8 mm. (5/16 inch).

3. — Ordinary thermometers are used in the shade.

4. — Fishplates are not lubricated.

III. — **Quality of metal in fishplates.**

1. — One uses Bessemer or Siemens steel, 38 to 42 tons per square inch tensile strength, minimum elongation of 12 % in 2 inches, and maximum reduction of 23 % in area; and the other Basic open track steel as in rails 55 tons per square inch tensile strength, minimum elongation of 10 % in 2 inches.

Chemical composition.

—	The first.	The second.
Carbon	0.35 to 0.50 °/₀	0.60 °/₀
Manganese	0.75 to 1.00 °/₀	0.75 °/₀
Phosphorus, maximum	0.06 °/₀	0.04 °/₀
Silicon, maximum	0.06 °/₀	0.06 °/₀
Sulphur. maximum	0.06 °/₀	0.04 °/₀

2. — Fishplates are not heat-treated.

3. — Special steel has not been justified.

4. — There are no definite records of broken bars. The number is insufficient to warrant special means for correction.

IV. — First cost of installing and maintaining joints.

1. — The first cost per joint is given as :

		Material.	*Labour.*	*Total.*
Road 1	6-hole	7 s. 8 d.	2 s. 8 d.	10 s. 4 d.
	4-hole	4 s. 5 1/2 d.	2 s. 2 1/2 d.	6 s. 8 d.
		Plates.	*Bolts.*	*Labour.*
Road 2	6-hole, 85-lb.	8 s.	1.4 s.	0.34 s.
		Total : 9.74 s.		

2. — Maintenance is estimated at :

6-hole fishplates	3 s. 2 d.
4-hole fishplates	2 s. 4 d.

3. — The average length of life of the rails, fishplates and bolts is estimated at twenty years.

4. — It is not the practice to use spring washers or lock nuts. The Whitworth thread (9 per inch) has been found sufficient.

QUESTIONNAIRE RESPONDENTS.

For the information used in the compilation of the report, the Reporter is indebted to fifteen members of the affiliated administrations, and to thirteen railroad companies in the United States and Canada not of the affiliated administrations.

APPENDIX.

Detailed list of questions relating to question II.

A. — Broken rails.

The breakage of rails in service may have serious results, and the causes should be examined to avoid a recurrence.

Usually there is nothing to distinguish a broken rail from its neighbours. It has been manufactured, laid and maintained in the same way, and has carried the same traffic as the others, and the cause of breakage must be looked for in defects in the metal from which it has been made.

When the breakage is due to the use to which the rails have been put, the cause is easily discovered and the remedy applied. It is not so, however, when the breakage results from internal defects in the metal, and the Reporters feel that it would be more profitable closely to study the latter type of breakage and the measures which railway managements should adopt to protect themselves against receiving rails which may contain such causes of failure.

The accompanying « questionnaire » has therefore been drawn up keeping in view this aspect of the case.

LIST OF QUESTIONS.

1. — Have you any statistics as to the number of rails broken annually on your railway?

By what rules or instructions are these statistics regulated ?

Give particulars, together with such further information as will enable a comparison to be made with the numbers on other railways, — such as age, weight and profile of rails, length of running track on the railway, number of train miles, maximum axle weight, highest speed of trains, etc.

2. — Breakages may be classified in a certain number of types, according to position, form, appearance, etc.

Have you made any such classification ?

Describe the types which your observations have led you to set up. Indicate the relative frequency of the breakages of each type in the last five years.

How do you consider the breakage has been started and has developed in each type, and what is, in your view, the initial cause ?

What methods of investigation have you followed in order to throw light on the process of formation of the fracture, and the actual causes in each type ?

3. — Breakages attributable to the use to which the rails are put.

Effect of age.

Taking rails supplied under certain contracts can you give for the total, and for each contract, the number of breakages of rails up to five years old, between five and ten years old, and so on for each five years ?

Effect of wear.

What reduction of profile (section, weight, etc.) do you allow before withdrawing from service rails carrying heavy traffic and those carrying light traffic ?

Effect of the elasticity of the formation.

Have you observed more breakages on a rigid than on an elastic formation ?

Effect of the inclination of the rail.

Do you consider that breakages are more frequent in rails placed vertically than in those placed at an inclination of 1 in 20, due to the effect of the rolling action near the edge of the rail ?

Effects of gradients.

Have you noticed more breakages on a rising than on a falling gradient, especially when, owing to signals, trains have frequently to start off on a gradient at the same point on the track ?

Effect of sleeper spacing.

Have you reduced the number of breakages by altering the number and spacing of the sleepers ?

Effect of corrosion.

Have you more breakages in the wet portions of tunnels?

Effect of work done on rails.

Have you noticed more frequent breakages of rails which have had work done on them in a cold or hot state, especially when such work has been done out on the line ?

Do the holes made in the portions of the rail covered by the fishplates or in the remaining length tend to cause breakage ? What effect have the diameter or the spacing of these holes and their distance from the end of the rail in this respect ?

Breakages in the length covered by the fishplates are more frequent than in the remainder of the rail.

Can you give :

1° the relative proportion of breakages per unit of length of rail covered by the plates, and per unit of length of the remainder of the rail;

2° the relative proportion of breakages in the trailing end which the wheel runs off, and the facing end on to which the wheel runs ?

What types of joint seem best to you from this aspect of the case ?

4. — Breakages attributable to defects in the metal in the rails.

Is the excessive amount of certain alloys a cause of breakage ? What do you consider the maximum permissible amounts from this point of view ? How do you detect these alloys ?

Is piping a cause of breakage ? How do you guard against piping ?

Is segregation a cause of breakage ?

What amount of segregation do you consider excessive, and how do you detect it ?

May not certain quite local defects be due to objectionable treatment in the manufacture of the rails (such as rails insufficiently protected against rain and snow while cooling, rails subjected to an undue amount of cold straightening, etc.).

5. — In order to lessen beakages have you used rails of special composition, such as sorbitic, heat treated, high tensile silicon, manganese, nickel, chrome, etc., and have you any statistical information as to the breakages in these rails ?

6. — What conditions do you propose to insert in your specification for the supply of rails to guard against the particular causes of breakage mentioned in question 4 ?

How far and by what conditions do you consider such a specification ought to fix the responsibility of steel makers supplying rails under contract in the event of accidents brought about by broken rails when enquiry attributes the breakage to a cause other than the use to which the rails have been put by the railway, that is to say to a defect in the metal ?

Do you think certain practices in the manufacture of the steel, tapping, rolling and finishing, should be prohibited ?

Describe them, giving the reasons for the prohibition.

B. — **Rail joints.**

Rail joints should be so constructed as to permit, so far as is necessary, free expansion of the rails, at the same time reducing to a minimum the shocks produced by the passage of the wheels, which produce discomfort to the passengers, fatigue of the rolling stock, and lastly deterioration of the materials in the track (rails, sleepers and fastenings).

The « questionnaire » has been drawn up with the view to elicit information on the respective advantages and disadvantages of the various types of joints actually in use or under trial and to enable comparisons to be made of the relative costs of instalment and subsequent maintenance, and the different railway managements to which the following questionnaire is addressed are requested to keep these points in view in replying to the enquiries.

LIST OF QUESTIONS.

I. — **Types of joints.**

1. — What types of joints are in use or under trial on your railway?

Describe them, indicating the exact relative positions of the joint and the adjacent sleepers, and indicating the nature and weight of the respective parts. Give drawings where necessary.

2. — What is the greatest distance between joints, *i. e.*, what is the greatest length of rail you use? Do you think it would be practicable or advantageous to increase them, and if so to what extent?

3. — Do you place the joints in the two rails of the same track opposite one another, or alternating? Do you consider that either method has any advantage over the other, and why?

4. — Joints are either suspended or supported, and in the latter case rest on the sleeper or on an elastic bridging piece between the two adjacent sleepers. Which of these arrangements do you consider the better and why?

In the suspended type, the joint may be placed at equal distances from or symmetrically to, the two adjacent sleepers or, on the other hand, may be placed unsymmetrically to these sleepers, being nearer the one on the facing or running on direction so as to reduce the deflection of the rail resting on that sleeper. Do you consider that the latter method presents any particular advantage over the former and if so, what are, in your opinion, the most suitable distances between the joint and the sleepers in the facing and trailing directions?

5. — Certain types of joints are designed with the object of preventing creep of the rails under the rolling action of the trains. Do you consider this an unsuitable arrangement, and that it is better to use means quite independent of the joints for the purpose of dealing with creep?

6. — There are types of joints in which the grip of the fishplate is secured, not by means of bolts, but y wedges and keys which hold the rail ends in special chairs fastened to the sleepers.

Do you consider that such joints, which do not require holes in the rail ends and fishplates, and consequently do away with the risk of breakage owing to such holes, offer particular advantages over other types of joints?

7. — In certain types of joints the upper edge of the outer fishplate is brought level with the rolling surface of the rail for the purpose of affording direct support to part of the rolling load. Do you think such a type offers any advantage over those in which the fishplates are not so raised?

8. — In certain types of joints the ends of the rails are not finished off square to their axis, but are cut in various ways and engage with each other (such as lapped or rebated

joints) or have the ends more or less inclined to the axis in a vertical or horizontal direction (such as oblique joints). Do you consider that the objections resulting from having to submit the rail ends to such extra treatment are conpensated for by the better hold of such joints under rolling loads ?

9. — There are marked differences in the angle of inclination of the fishing surfaces of rails and fishplates in various types of joints. What particular angle of inclination do you favour, and why ?

10. — There are marked variations in length of fishplates, and number of fishbolts, in different types of joints. What particular arrangement do you consider most suitable, and why ?

11. — After the fishplates have been screwed up there may sometimes exist slight irregularities of level between the rolling surfaces of the two rails thus connected. Do you think it of advantage to remove these irregularities by planing down the rolling surfaces, and if so, do you use any special appliance for the purpose, and what is it ?

12. — When owing to wear of the contact surfaces fishplates no longer retain a good hold of the joint, the trouble may be remedied by the use of various arrangements which temporarily restore to the joint its lost properties. Among others may be mentioned :

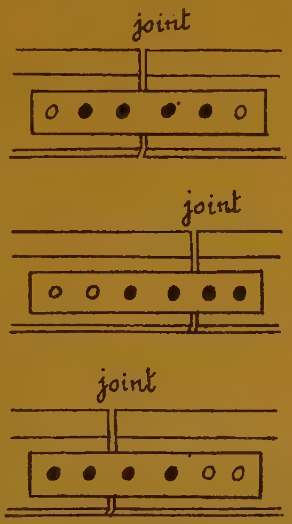
The use of fishplates with increased height (to compensate for the wear of the fishing surfaces of the rail ends).

The placing between the fishing surfaces of rails and plates of narrow metal strips of suitable shape to stop the existing play.

The displacement, in a trailing or facing direction, of the two fishplates of the joint, which, with this object, are made of greater length than is usual and have additional holes for the fish bolts. Such plates can, in consequence, be placed in the three successive positions, shown on the accompanying sketch in which the marked holes in each figure are those utilised for bolts, the remaining holes not being required for the time being.

In the same category may be mentioned the renovating, with a view to their re-use, of worn fishplates by reforging, so as to restore their dimensions between the fishing surfaces, or even slightly to increase their dimensions, so as to compensate for the wear of the rails which they connect.

Have you employed any of these methods, and have you any preference for any of them, and why ?



13. — What types of insulated joints do you use for track circuits ? Give drawings and set out the advantages and disadvantages of such types.

II. — **Freedom for expansion of rails.**

1. — *a*) What maximum calculated gap between the rail ends is provided for by your design of joint, leaving out of account tolerances and variations in manufacture ?

When tolerances and variations in manufacture are taken into account in addition to the calculated provision as designed, what are:

b) the greatest possible gap at the joint,

c) the least possible gap at the joint, the ends of the two adjacent rails being drawn away as far from one another as practicable ?

If the sizes of the holes in the rails and plates vary with the length of the rails joined together please give, for each size, the particulars for *a*), *b*) and *c*), and the maximum corresponding lengths of rails.

2. — What rules, depending on temperature and length of rails, do you work to in settling the amount of play to be allowed between the two ends of adjacent rails when in tunnels and in the open ?

3. — How do you fix the temperature ? Do you use special thermometers, and if so, what are their particular features ? Are you satisfied to take the surrounding atmospheric temperature in the shade, or do you endeavour to ascertain the temperature of the rails themselves ? In the latter case how do you ascertain it ?

4. — Do you use any system of lubrication to reduce friction between the rails and plates, and thus allow free expansion and contraction of the rails ? If so, what do you do ?

III. — Quality of metal in fishplates.

1. — What are the characteristics (tensile strength, percentage of elongation, chemical composition, etc.) of the metal you specify for the manufacture of fishplates ? Do you insist on the use of Open-hearth steel, or are you satisfied with Thomas or Bessemer steels?

2. — Do you submit fishplates to heat treatment after manufacture ? If so, what is the nature of the treatment (simple annealing, tempering by complete or partial cooling, tempering followed by annealing, etc.), and what results do you obtain ?

3. — Are you of opinion that it would be advantageous to use special steel for fishplates (high tensile, manganese, nickel, chrome, etc., steels) and why ?

4. — Are broken fishplates a frequent occurrence on your railway ? What is the number per mile of track per annum ? What are the principal causes to which they may be attributed, and what means are you considering to eliminate them or reduce their number ?

IV. — First cost of installing and maintaining joints.

1. — Based on the prices ruling in the first half of 1914, what is the cost of installing each type of joint in use or under trial on your railway ? This price, which should cover the pair of joints for one track, *i. e.*, one for each rail, should exclude the cost of ballast, sleepers, and rails, but should include, where applicable, any extra cost due to special sleepers or chairs, cutting the ends of the rails (such as lapping, rebating or forming oblique ends) or to any other reason.

2. — At what sum (values as in the first half of 1914) do you estimate the annual cost of maintaining each of these types of joints ? In these costs should be included all necessary expenses for keeping the joints tight under rolling loads, that is to say not only those for replacing the various parts, but also for ordinary maintenance (tightening of the bolts, supplying and putting in position wedges or metal strips to take up play; more frequent lifting and packing of the joint sleepers, etc.);

3. — What is the average length of life of the different parts of the joint ? How do you dispose of these parts when they can no longer be left in the line ? If you re-make worn fishplates or recondition bolts damaged in use, what is (in 1914 prices) the cost of these operations in each case ?

4. — Have you made use of any particular methods (such as spring washers and plates, lock nuts, etc.) in order to reduce maintenance costs due to tightening up of fish bolts ? If so, have you obtained satisfactory results ?

5. — Have you employed any other means of lengthening the life of the various parts of the joint, or of reducing the expense of their maintenance ? If so, describe them and the results which you have obtained.

[656 .212.5]

REPORT No. 2

(America)

ON THE QUESTION OF SHUNTING YARDS (SUBJECT III FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

By Samuel T. WAGNER,
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Figs. 1 to 10, pp. 836 to 846.

The report submitted herewith is intended to illustrate the practice on a number of the leading railroads in the United States and Canada.

The information was obtained in response to a questionaire intended to allow each railroad to submit a type of yard which they considered representative and give the data required in the questionaire as to « Layout and Organization ». This data is shown in appendices 1 and 2.

The *Manual of the American Railway Engineering Association* (1921) gives the following definitions relative to the subject under discussion :

Yard. — A system of tracks within defined limits provided for making up trains, storing cars and other purposes, over which movements not authorized by timetable or train order may be made, subject to prescribed signals, rules and regulations.

Classification yard. — A yard in which cars are classified or grouped in accordance with requirements.

Gravity yard. — A yard in which the classification of cars is accomplished by gravity.

Poling yard. — A yard in which the movement of cars is accomplished by the use of a pole operated by an engine on an adjacent parallel track.

Summit or hump yard. — A yard in which the movement of cars is accomplished by pushing them over a summit, beyond which they run by gravity.

Separating yard. — A yard in which cars are separated according to district, commodity or other required order.

Sorting yard. — A yard in which cars are classified in greater detail after having passed through a classification yard.

General.

President E. F. Loree in his book « Railroad Freight Transportation » divides yards for the assembling and classification of freight, into : 1° Shunting yards; 2° Poling yards; 3° Hump yards; 4° Gravity yards.

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(1) This question runs as follows : « Shunting and marshalling yards for goods trains. Lay-out and organisation. »

This subdivision will be used in the subject under discussion, and each will be treated separately under « Layout and Organization » and « Operation ».

In addition to the general layout of tracks, which will be considered in each case separately, there are certain essential adjuncts which may be required to a greater or less degree depending on the uses, size and general location of the yard.

Engine house. — In any large yard appliances for caring for engines will be required for housing and making light repairs. These should be located so as to be of easy access to the various parts of the yard, with sufficient tracks to hold engines awaiting their turn to go on the road. It should be equipped with an adequate number of stalls and with a machine shop of suitable size and provided with tools to make the repairs required. Drop pits for handling the wheels, inspection pits, heating and lighting are necessary as well as hot water wash off and boiler wash facilities.

Coaling stations, ash pits, water stations, sanding facilities, inspection pits. — These should be located conveniently to the engine house to prepare engines for service. The extent and detail of these facilities will depend on the number and characteristics of the engines to be handled. They are usually located so that an engine moving over them will pass in the order required and make no extra movement. Coaling stations for supplying fuel to the engines may be of the simplest kind with small fuel storage or of the most improved mechanical type for the larger stations, specially where room is an important feature. Coal mixing facilities may also be required. Ash pits are now generally preferred of a type which will allow the ashes to be dumped into water, before being removed.

Car repair shops, yard offices, stock pens, yard lighting. — Shops, for making repairs to cars, furnished with transfer trestles for transferring contents into other cars in case of general disablement; yard offices to house the yard organization; stock pens to feed and water live stock in transit; quarantine pens for health inspection of stock; general lighting of the yard to allow of work to be done with safety at night are all essentials of a yard of any magnitude.

Practically all of these adjuncts are of sufficient importance to be made subjects of independent investigation. The scope of this paper, however, prevents their further elaboration here.

Layout and organization.

1° *Shunting : Classification yards.*

In yards of this class, sometimes known as « Push and Pull » yards, « Link and Pin », or « Tailswitching » the movements through the yard are made by a switching or possibly by a road engine, alone. Such yards are neither efficient nor economical in operation, but there are many localities, specially in congested districts, where nothing else is possible and it is particularly true of yards of small capacity and handling a limited business. The design of such yards is usually attended with conditions which leave small latitude to the ingenuity of the designer as to development of economies. In them every car is required to be placed by a special movement of the engine. On account of their disadvantages in operation and the uncertainty of the conditions surrounding their design they will not be considered at further length.

2° *Poling yards.*

Yards of this type are so superior to the plain « Shunting » or « Push and Pull » yards that their design warrants the most careful study. They are undoubtedly one of the best methods that can be used for the separation and classification of cars, but not the most economical except in cases where the volume of business handled is small. They require a separate track alongside the entrance to the yard on which the « engine or ram car » can be operated. This engine, or a specially constructed « ram car » has a pole attached to it which is operated so as to come in contact with the « poling pocket » on the last car of the cut to be made. The ram car is usually equipped with four poles, two on each side, one forward and the other in the rear.

The operation of poling is hard on the equipment. The cars require a heavy start and this action is hard on the engine. Without an assisting grade, a heavy business requires the incoming train to be pushed by an engine, as the « cut cars » are pushed ahead by the « ram car ». A descending grade of 0.5 % is valuable but even 1.0 % may not be too steep. In some cases the poling may be done directly from the receiving yard into the classification yard.

An advantage of poling yards is the facility with which cars may be started at varying speeds in entering the classification yard. Differences in character of equipment; whether the cars are loaded or empty and similar conditions make the poling proposition a very elastic one to suit varying conditions. Again, a poling yard when it has the assistance of gravity has much in its favor.

3° *Hump yards.*

The American Railway Engineering Association has in its 1921 Manual laid down certain facts relative to yards of this class, which are so well expressed that they are given in full as follows :

1. Hump yards should consist of receiving, classification and departure yards in consecutive order.
2. A hump yard is a desirable form of yard for receiving, classifying and making up trains, because a greater number of classifications can be made in less time and at less cost than through any other form of yard.
3. Receiving tracks should be of sufficient length to hold maximum trains of the various classes handled.
4. Receiving tracks should be sufficient in number to hold a number of trains arriving in quick succession. The number will depend on the amount and character of traffic handled, and upon the relative location of the yard with respect to the other yards and connections.
5. If it is possible, the grades of the receiving tracks should be such that one engine can push the maximum train over the hump.
6. No definite recommendation can be made as to the length or number of classification tracks, except that when they are to be used as departure tracks they should be long enough to hold full trains; and that when conditions permit there should be as many of them as can be used to advantage to avoid subsequent classification and consequent delay.
7. Departure tracks should be full train length and of sufficient number to provide ample standing room for trains while being tested for air, and while waiting for engines.

8. An air brake testing plant should be provided in the receiving and departure yards. Pipes should be laid along the tracks and sufficient outlets furnished (with hose) to test air brakes on all trains.

9. To secure the greatest possible efficiency or to so construct a hump that the greatest number of cuts may be classified over it, the steepest part of the grade should be reached in the least available distance after passing the summit and the grade or fall should provide sufficient momentum to carry all cars to the lower ends of classification tracks.

10. The hump profiles in figure 1 are recommended as follows: No. 1 for cold climates; No. 2 for moderate climates; No. 3 for warm climates. These are for humps with track scales and operating a mixed traffic of merchandise and empty cars.

11. Where traffic or climatic conditions require, the summit of a hump may be made higher in the winter and restored when the increased height is not needed.

12. When required by traffic conditions, a track scale not exceeding 60 feet in length should be located at such a distance from the summit of the hump, that when cars to be weighed reach the scale they will be properly spaced from following cars and will be running slowly enough to easily secure correct weights.

13. For average conditions it is recommended that No. 8 frog be the sharpest used in classification yards.

14. Where tracks are set aside for holding empty cars, the grade leading to such empty track should be increased so that such empty cars will move with the same velocity as loaded cars switched to adjacent tracks.

15. The cut list system of handling cars on the hump is recommended as being efficient; it is briefly described as follows: The yard clerk makes up a list of cars to be switched and the tracks they are to be placed on in the receiving yard, cut No 1 being the first *cars* to go over the hump. It is perforated on vertical lines, so that it may be divided into multiple parts, each part being a duplicate of the other. (See example cut list.)

Form for cut list system of handling cars on the hump.

Cut list.			Cut list.		Cut list.		Cut list.	
No. of cut.	No. of track.	Cars in cut.	No of track.	Cars in cut.	No. of track.	Cars in cut.	No. of track.	Cars in cut.
1								
2								
3								
4								
5								
6								

Where switches are thrown from a tower one copy of the list is given to the towerman and one to the man cutting off cars on the hump.

Where switches are thrown by hand, each switch tender has a copy of the cut list, as well as the man cutting off cars on the hump.

The hump yard has in the past 25 years come into such general use that it has practically become standard on all roads where conditions allow it to be used. It is stated that probably the largest yard in the United States of this kind is the Chicago Union Transfer Railway at Chicago, Ill. It is over 25 miles long, contains 105 miles of track and will hold 14 000 cars.

The ease with which the hump can be used to facilitate classification and the advantages of operating yards economically has caused it to come into general use. It is specially adapted to cases where a large volume of business is to be handled. The question of gravity assisting grades in hump yards is one of the most difficult parts of the design specially when the yard is used with separate receiving, classification and departure yards.

The Committee on « Yards and Terminals » A. R. E. A. in 1914 reported on several features of the design of hump yards (vol. 15, p. 131) from which the following are abstracted.

« Reports from 24 yards show that at least 800 cars must be handled daily to warrant the use of a hump yard.

29 hump yards reporting show that 16 have departure tracks and 13 have none. This same Committee in 1922 fail to agree on a recommendation as to the necessity of departure tracks.

Of 15 yards reporting, 9 have scales on the hump and 6 have none »

The hump may be frequently introduced in an existing yard with light business and effect economies in operation.

4° *Gravity yards.*

Yards in which humps are not used and which are operated only by the use of grades sufficient to make the necessary classifications, are rare because it is extremely difficult to find topographical conditions such as will allow a design to be made with economy. When however such a location can be found it makes an ideal condition from an economical standpoint as the movement from the receiving yard into and through the classification yard can be made without any additional power. The difficulty is in finding a broad tract of land with a descending grade sufficient to allow cars to move by gravity at any point.

General discussion.

Based on information received from the questionnaire and other available data the following points are elaborated upon in some detail as representing what is believed to be good practice in the Layout and Organization of « Shunting » or « Classification » yards.

Layout and organization.

Organization. — The organization of a yard consists of foremen, general yardmasters, yard engine and train crews, clerical forces, transfer laborers, switchmen. The size of the force depends on the size of the yard and the amount of traffic handled. A very high grade of man is required in the official and supervisory positions on account of the peculiar conditions which are always changing.

Design. — The majority of the railroads reporting appear to favor the « Hump yard » as the best means of classification. There are also several cases of « Gravity yards » which are in use where the local conditions favor their construction.

Grades. — This question is a very difficult one to summarize. Anything but very complete plans would fail to show the essentials. An attempt has been made to show on the plans of the yards submitted the essential grades.

Number of tracks. — The number of tracks required of course depends on the general location of the yard with reference to other yards and terminals and also with reference to the amount and diversity of traffic, classifications required, etc.

Car capacity. — The capacity of the yard in cars can probably best be determined by comparing the capacity with the number of cars handled in 24 hours, or its equivalent.

Radii of curves and frog numbers. — It can be safely said that the minimum radius of tracks is about 500 feet and the minimum frog number should not be less than No. 8 (ratio 1 to 8).

Location of main tracks. — Probably the majority of the large yards are located with the main running tracks located on each side of the yard with the yard itself and all of its appurtenances located between. This is preferable for many reasons principally because there is no interference with the operation of the main tracks by shifting in the yard and passage to and from the engine facilities. In some cases however the main tracks run through the centre of the yard.

Weight of rail. — The weight of rail in yards is generally the same or slightly less than in the main running tracks, unless the running tracks are laid with very heavy rail. From data obtained it would appear that weights of rail run from 85 to 105 pounds per yard.

Track scales. — Scales with a capacity of 150 tons and a length of from 50 to 60 feet are generally used. Single scales are most frequently used. It is not the practice to use mechanical humps before reaching the scale and a dead track is almost always used over the scale.

When track scales are used in hump yards they are usually placed from 100 to 150 feet from the summit of the hump. In other yards local conditions determine their location. Where cars are weighed while in motion speeds of from 3 to 4 miles per hour are customary.

Car repair tracks. — Ample tracks must be provided and set aside for holding cars for repairs.

Engine repair tracks. — In connection with the engine facilities, tracks must be provided to take care of light repairs. They should be located adjacent to the engine house. They should be located so as to be in regular sequence to the movements of the engine. Arrangements should be made so that yard engines can have their fires cleaned and can take coal and water without interfering with other engines undergoing inspection and or repairs.

Advance yard. — There is a decided difference in opinion concerning advisability of having an advance or receiving yard for holding trains before they reach the classification yard, but, if a « Hump » or « Gravity » yard is used and the traffic is heavy and liable to be bunched at times, such yards are almost indispensible. Most of the larger yards are so provided.

Auxiliary sorting yards. — Such yards may be advisable if they can be secured advantageously, specially where the classification tracks are not long enough to hold full length trains.

Air brake testing. — The departure tracks specially should be provided with piped air lines from a compressor to test the air brakes so that all cars can be tested before the train leaves the yard. If there is no departure yard the tracks in the classification yard should be so equipped.

Thorofare tracks. — The best practice always provided thorofare or some special tracks to insure the prompt movement of road engines free from yard interruptions. These tracks can also be used to pass trains directly through the yard if necessary.

Caboose tracks. — Tracks for holding cabooses ready for trains to go on the road should be located so that cabooses can be handled with the minimum amount of switching.

Turning engines. — In practically all yards engines are turned on engine turntables although an auxiliary « Y » or loop is of great advantage if it can be located without interfering too much with the other yard facilities.

Jitney service for hump brakemen. — In hump yards, facilities should be provided to transport the hump brakemen back to the hump. An engine or motor cars are usually used for this purpose.

Operation.

The Committee on Yards and Terminals, « American Railway Engineering Association », in volume 15, page 131 (1914), summarize a number of points derived from a questionaire sent out at that time from which the following notes are abstracted.

The questionaire related to « Hump Yard » but at least one question related to the operation of flat yards.

« 28 hump yards reported an average cost of 21.2 cents per car for handling.

11 *flat yards* reported an averge cost of 22.91 cents per car.

22 hump yards reported an average of 72 cars handled per hour.

24 hump yards reported an average of 1973 cars handled per 24 hours.

24 yards regulate the number of car riders according to the business, in sight; 4 have no definite rule and 1 figures on the basis of 7 cars per rider per hour.

23 yards maintain an extra list of car riders and draw on it as required; 4 maintain an extra list of switch tenders and use switch tenders as car riders as required »

Reference is made to appendix 1 as to details of operation of the various railroads reporting on the question of « Operation ».

SUMMARY.

The subject matter reported upon involves the consideration of yards under the following nomenclature :

1° Shunting yards;
2° Poling yards;
3° Hump yards;
4° Gravity yards

and the summary of the investigation appears to warrant the following conclusions :

1° *Shunting yards* sometimes known as « Push and Pull », « Link and Pin », or « Tailswitching » are the most common, and are used where a more elaborate layout is impossible and generally where the amount of business is relatively small. Under these conditions they are warranted and advisable.

2° *Poling yards*, where the classifications are made by a poling engine they are much more economical than the plain shunting yard. They require a much more extensive layout but are warranted where there is sufficient business to justify the cost of their construction.

3° *Hump yards*, where the cars are pushed over a summit into the classification yards are the type mostly used where a large volume of business is handled, in which case a greater number of classifications can be made in less time and at less cost than through almost any other form of yard.

4° *Gravity yards*, where the classifications are made by gravity alone are ideal as no other force than gravity is required in the classification. They are very economical but are rare, as it is seldom that ground can be found with topographical features that would allow such a yard to be built without extraordinary expense.

APPENDICES

APPENDIX I.

QUESTIONNAIR

Shunting yards : Shunting a

Index number.	DESCRIPTION.			ORGA	
	Name of railroad.	Name of yard.	Location of yard.	Supervisory officers and employees.	Is your car inspection force properly constituted, locate and equipped.
			COLUMN. . .	1	2
1	*Elgin, Joliet & Eastern Railway Co.*	East Joliet.	Illinois.	Officers .... 25 Employees . 2 109	Yes.
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	Officers .... 20 Employees... 715	Yes.
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	...	...
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	Officers .... 50 Employees . 1 032	Yes.
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Officers.... . 15 Employees... 430	Yes.
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Officers...... 39 Employees... 868	Stationed where needed in the yard. Available at all times.
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Superintendent trainmasters, foremen, switchmen, inspectors, laborers etc.	Yes.
8	*Erie Railroad Company.*	Port Jervis.	New York.	Officers...... 51 Employees... 983	Yes.
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	Officers...... 19 Employees... 231	Yes.
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	Superintendent, trainmaster, yard masters, foremen, inspectors, switchmen and laborers.	Yes.

halling yards for goods trains.

ON.	DESIGN.			
o you have loyees assigned o take care of cabooses handle supplies for same.	*General purposes of yard.*	*Specific purposes of yard.*	*In design of yard what method of operation do you favor.*	*Grades on approach to summit and down to the end of yard.*
3	1	2	3	4
Yes.	Classification of trains.		Gravity.	Do not use hump yards.
No. ll supplies obtained y conductor.	To relieve congestion at Hoboken.	Classification of trains.	Hump.	Freight: + 2.75 °/o for 100 ft.; — 1.5 °/o for 380 ft. Average: + 0.12 °/o to end. Coal: + 2.5 °/o for 210 ft. Average: — 1.43 °/o for 950 ft.; + 0.15 °/o to end.
...	Classification of coal originating in the anthracite district.	To relieve nearby yards and classify coal near center of production.	Hump yard where there is a considerable volume of business.	+ 2.0 °/o with 30 ft. v. c. — 2.0 °/o over scales. — 3.5 °/o for 200 ft. — 2.0 °/o for 300 ft. — 1.2 °/o for 400 ft. — 0.5 °/o and level to end of yd.
Yes.	To provide facilities for classifying trains.	To expedite movement of freight.	A hump and gravity combination.	Receiving yard level or slightly descending grade toward the hump.
abooses are pied by crews d taken care of by them.	Classification yard.	Division terminal and tranfer station.	Hump.	+ 1.5 °/o for 25 feet ±. Level for 29 feet ±. — 4 °/o for 37.5 feet. — 0.8 °/o for 89 feet. — 3 °/o for 100 feet. — 1.25 °/o through yard.
uties of rear keman of road nd transfer rain crews.	To provide terminal facilities.	For receipt, classification and dispatch of road freight	Hump, where traffic is heavy, otherwise push and pull.	West bound: + 2 °/o approach. — 2 °/o for 150 feet. — 3 °/o to — 0.5 °/o for 1 300 ft.
ain crews keep abooses clean and car staff dle all supplies.	General yard purposes.	Receiving, classification and forwarding of trains.	Pull and push or hump according to amount of business.	Grades shown on plan are satisfactory.
Taken care by train crew nd supplies cured by them he store room.	Classification and making up of solid trains for various destinations and junction points.		Hump.	+ 3.166 °/o for 120 feet. — 1.85 °/o for 200 feet. — 1.05 °/o for 200 feet. — 1.25 °/o for 200 feet. — 1.133 °/o for 150 feet.
Yes. man is assigned o this work.	Making up of trains, classifying loads and storage.	Making up ore trains and coal trains.	Push and pull used.	No hump in this yard.
Crews look ter their own oses and secure supplies m storekeeper.	To receive, classify and dispatch trains on B. & O. system.	To receive from and forward to individual terminals.	Favor a hump or summit yard.	+ 1 ft. in 60 ft.; — 2 °/o for 60 ft.; vertical curve for 40 ft.; — 4 °/o for 50 ft. vertical curve for 155 ft.; 1 °/o through ladders and 0.5 °/o to end of yard.

APPENDIX I. (*Continued.*) QUESTIONNAI

Shunting yards : Shunting

	DESCRIPTION.			ORG	
Index number.	**Name of railroad.**	**Name of yard.**	**Location of yard.**	*Supervisory officers and employees.*	*Is your car inspection for properly constituted, loca and equipped*
			COLUMN. . .	1	2
11	*Southern Pacific Company.*	Roseville.	California.	Superintendent, trainmasters, foremen, switchmen, laborers, etc.	Yes.
12	*New York Central Railroad Company.*	Selkirk.	New York.	Yard masters, mechanics, car builders, foremen, clercks, and laborers.	Yes.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	Officers . . . . . . 66 Employees . . . 375	Yes.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	Officers . . . . . . 15 Employees . . . 199	Yes.
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	Officers . . . . . . 9 Employees . . . 108	Yes.
16	*Reading Company . .*	St Clair.	Pennsylvania.	Officers . . . . . . 25 Employees . . . 995	Inspectors locat at North and So ends of yard.
17	*Reading Company . .*	Rutherford.	Pennsylvania.	Officers . . . . 40 Employees . 1 140	Inspectors locat in all yards.
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	Officers . . . . . . 22 Employees . . . 643	Yes.

shalling yards for goods trains.

TION.	DESIGN.			
Do you have ployees assigned to take care of cabooses handle supplies for same.	*General purposes of yard.*	*Specific purposes of yard.*	*In design of yard what method of operation do you favor.*	*Grades on approach to summit and down to the end of yard.*
3	1	2	3	4
Yes.	Break up and make up yard.	Receiving and re-dispatching trains to destinations	Push and pull, shunting.	No hump in Roseville yard.
Yes.	Receives freight from points East and West, making all general classifications accordingly.		Hump or summit.	W. B. :—1.5 °/o for 1 660 feet. 0.0 °/o for 40 feet. 3.5 °/o for 200 feet. Aver. : 1.25 °/o for 1 000 feet. E. B. : 1.0 °/o for 150 feet. 0.0 °/o for 40 feet. 3.0 °/o for 150 feet. Aver. : 0.625 °/o for 1 800 feet.
This work andled by road crews.	Blocking out trains for points East and West.	Sorting cars for grain elevators, oil refineries, etc.	Would favor hump method.	We have no hump.
re of cabooses is y of train crew. Supplies are nished at other terminals.	Interchange of traffic between railroads.	Receiving, departure and classification.	Hump if topography will permit.	E. B. : + 0.8 °/o; 1.38 °/o to 2.26 °/o for 250 feet; Av. : 0.21 °/o for 2 900 feet. W. B. : + 2.1 °/o; — 3.5 °/o for 100 feet; — 0.8 °/o for 600 feet; — 2.5 °/o for 1 300 feet; + 0.43 °/o for 1 400 feet.
Yes.	Receiving, classification and departure.	Trains from four divisions are consolidated and classified at this yard.	Hump, where traffic is heavy, otherwise push and pull.	We have no hump yards.
No.	Handling anthracite coal.	Weighing and classifying coal and freight.	Gravity.	No hump on account of gravity type.
sub-store house ast bound yard. o one assigned to this work.	Division terminal point for handling power and cars.	To classify cars in solid trains.	Hump operation.	W. B. : + 1.0 °/o for 450 feet. — 2.5 °/o for 200 feet. Level for 3 200 feet. E. B. : + 2.6 °/o for 70 feet. — 2.0 °/o for 100 feet. — 0.99 °/o for 4 400 feet.
Handled y train crew.	Receiving, classifying and forwarding freight trains.		Hump method.	— 0.64 °/o for 102 ft.; vertical curve 40 ft.; — 4.0 °/o for 50 ft.; — 3.0 °/o for 80 ft.; — 2.3 °/o for 100 ft.; — 1.7 °/o for 100 ft.; — 1.3 °/o through ladders; average: — 0.3 °/o to end of yard.

APPENDIX I. (*Continued.*) QUESTIONNA

Shunting yards : Shunting

Index number.	DESCRIPTION.			DESIGN.			
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Number of tracks.*	*Car capacity.*	*Minimum radii.*	*Length*
			COLUMN. . .	5			
1	*Elgin, Joliet & Eastern Railway Company.*	East Joliet.	Illinois.	71	2 724	460 feet.	
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	90	4 007	603 feet.	64
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	31	2 130	603 feet.	64
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	60	3 400	...	66
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	56 and other miscellaneous tracks.	3 827	5 680 feet.	65
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	132	8 210	942 feet.	79
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	133	7 332	...	
8	*Erie Railroad Company.*	Port Jervis.	New York.	16	975	499 feet. 764 feet.	

STIONNAIRE. APPENDIX I. (*Continued.*)

shalling yards for goods trains.

DESIGN. (*Continued.*)						
Frog numbers.	*Car capacity: length of car allowed.*	*Layout: small scale plan.*	*Location of main tracks.*	*Weight of rail.*		*Wye track. General description.*
				Yard tracks.	*Main tracks.*	
5	6	7	8	9		10
...	50 feet.	...	Along one side.	80 lb.	85 lb.	None.
o. 8	40 feet.	...	Through center of yard.	80 lb.	105 lb.	None.
o. 8	42 feet.	...	Between the yards and the round house.	91 lb.	91 lb.	None.
o. 8	40 feet.	...	Outside of yard.	100 lb. and 80 lb.	107 lb.	Wye track at end of yard opposite turntables and clear of yard.
o. 8	40 feet.	...	Through center of yard.	80 lb. to 90 lb.	100 lb.	East leg 520 feet long. West leg 550 feet long. 18° curve. Tail track 80 feet long.
o. 10	43 feet	...	On outside and through center of yard.	85 lb.	100 lb.	None.
...	42 feet.	...	Outside and through yard.	85 lb.	85 lb.	None.
o. 8 o. 10	42 feet.	...	Through middle of yard.	90 lb.	100 lb.	14° Back of rail shop.

APPENDIX I. (*Continued.*) QUESTIONNA

Shunting yards : Shunting

Index number.	DESCRIPTION.			DESIGN.			
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Number of tracks.*	*Car capacity.*	*Minimum radii.*	*Length*
			COLUMN. . .	5			
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	74	3 900	...	
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	145	8 230	...	77 67
11	*Southern Pacific Company.*	Roseville.	California.	44	1 740	406 feet.	
12	*New York Central Railroad Company.*	Selkirk.	New York.	127	8 460	...	
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	68	4 524	602.6 feet.	68
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	42	2 081	603.8 feet.	
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	42	3 025	516 feet.	68
16	*Reading Company* . .	St. Clair.	Pennsylvania.	66	2 010	390 feet.	65
17	*Reading Company* . .	Rutherford.	Pennsylvania.	84	5 220	477 feet.	65
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	121	9 893	...	

ESTIONNAIRE

arshalling yards for goods trains.

DESIGN. (*Continued.*)

Frog numbers. 5	*Car capacity: length of car allowed.* 6	*Layout: small scale plan.* 7	*Location of main tracks.* 8	*Weight of rail.* 9		*Wye track. General description.* 10
				Yard tracks.	*Main tracks.*	
No. 8	40 feet.	...	Along east side of yard.	85 lb. 100 lb.	100 lb.	15° curve on two legs No. 8 frogs.
No. 10 No. 8	42 feet.	. .	Around yard on outside.	85 lb.	100 lb.	No wye at this yard.
No. 7 No. 9 No. 10	45 feet.	...	Center of yard.	75 lb. 90 lb.	90 lb.	West leg on 8° 46′ curve. East leg on 10° 15′ curve.
No. 8 No. 10	42 feet	...	On either side of yard.	105 lb. and 80 lb.	105 lb.	Wye or loop track 12° 52′ curve.
No. 8 No. 10	45 feet.	...	Passenger on South & freight on North side.	85 lb.	90 lb.	East leg 13° 00′ curve West leg 10° 00′ curve.
No. 8	40 feet.	...	Along one side of yard.	100 lb.	100 lb.	No wye tracks used.
No. 8	42 feet.	...	Outside of yard.	70 lb. to 80 lb.	100 lb.	None.
No. 8	33 feet.	...	On both sides.	78 lb. 90 lb. 100 lb.	90 lb. 100 lb.	Loop track in place of wye track.
No. 8	40 feet.	...	On both sides.	90 lb.	100 lb.	None.
No. 8	42 feet.	...	On either side of yard.	Worn rails from main track.	130 lb.	None.

APPENDIX I. (*Continued.*)

QUESTIONNAIR

Shunting yards : Shunting ar

Index number.	DESCRIPTION.			DESIGN.					
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Scales.*				*Is a mechanical hump used before reaching scales.*	*Is there a dead track or relieving gear on scales.*
				Size, in feet.	*Capacity, in tons.*	*Single.*	*Double.*		
			COLUMN. . .	11				12	13
1	*Elgin, Joliet & Eastern Railway Company.*	Eat Joliet.	Illinois.	...	100	1	...	No.	Dead track.
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	No track scales; track scales located at Hoboken.					
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	There is no weighing done in this yard.				No scales.	No scales.
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	54 54	150 150	Pair. 1	 ...	No.	Dead track.
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	52 (Coxton yard)	150	1	...	No.	Dead track.
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	50	150	2	...	No.	Dead track.
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada	...	150	1	...	No.	Dead track.
8	*Erie Railroad Company.*	Port Jervis.	New York.	56	150	1	..	No.	Dead track.
9	*Bessemer & Lake Erie Railroad Company.*	Albion	Erie Co., Pa.	46	100	1	...	No.	Dead track.

arshalling yards for goods trains.

DESIGN. (*Continued.*)

Advise facilities for car repair, storage of materials and engine shops.	*Is an advance yard desirable or necessary.*	*Advisability of providing an auxiliary or sorting yard.*	*Bad order and repair tracks so located as to require the least amount of engine service.*	*Are compressed air lines installed to charge brake equipment.*	*What provisions have been made to insure prompt movement of road engines.*	*What facilities have you for trains passing through the yard without switching.*
14	15	16	17	18	19	20
18 locomotives. 3 200 cars light. 1 600 cars heavy. Repairs per month.	Yes.	No.	Yes.	Yes.	Separate running tracks.	No trains pass through without switching.
8 car repair tracks. Lumber stored in material building.	Yes, when traffic is heavy.	No.	Yes.	Yes.	Run around tracks are provided.	Main tracks and crossovers.
3 car repair tracks. 24 cars capacity built on 20 feet centers. Large engine and car repair shops.	Yes, when a full train can be placed on one track.	Yes, for better grouping.	Yes.	Yes.	Crossovers and slip switches at end of receiving yard.	Long tracks along side of classification yard and main tracks.
Light repairs to cars. Locomotive repairs. Made in machine shop. Mill building.	It is desirable.	Yes.	Yes.	Yes.	Separate receiving classification and departure units.	Trains run direct to departure yard. Change crews and power.
Car repair tracks for 30 cars. Limited supply of material. Light repairs to engines.	No.	Not necessary.	Yes.	Yes.	Separate tracks for west bound engines.	Such trains pulled in on any available track
Car repair tracks for 260 cars. Locomotive repairs at engine terminal. Material stores.	Yes.	Yes, if outbound cars accumulate.	Tracks located with respect to engine service.	Yard is so equipped.	Running tracks and exclusive engine tracks.	Trains occupy tracks set apart for through movements.
11 car repair tracks. 160 cars capacity. 30 stall engine house. Material stores, etc.	Not required at this yard.		Yes.	Yes.	Main and thoroughfare tracks; see plan.	
18 car repair tracks. 32 stall engine house. Car and engine repair shops.	Yes, with hump operation.	Yes.	Yes.	Yes.	Thoroughfare tracks so located.	Either on main tracks or through thoroughfare tracks.
Light repairs to cars and engines. Very little material is stored.	Not used in this yard.	Not necessary.	Yes.	No.	Separate tracks to and from engine house.	Trains use main track or the running track.

Shunting yards : Shunting a

	DESCRIPTION.			DESIGN.					
				Scales.					
Index number.	**Name of railroad.**	**Name of yard.**	**Location of yard.**	*Size, in feet.*	*Capacity, in tons.*	*Single.*	*Double.*	*Is a mechanical hump used before reaching scales.*	*Is there a dead track or relieving gear on scales.*
			COLUMN. . .	11				12	13
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co. Maryland.	50	150	1	...	No.	Dead track.
11	*Southern Pacific Company.*	Roseville.	California.	...	150	1	...	No.	Dead track.
12	*New York Central Railroad Company.*	Selkirk.	New York.	...	100	1	...	No.	Dead track.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	46	150	3	...	We have no hump.	Dead track.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	52	100	1	...	No.	Dead track.
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	50	150	2	...	No.	Dead track
16	*Reading Company* . .	St. Clair.	Pennsylvania.	60	125	1	...	No.	Dead track.
17	*Reading Company* . .	Rutherford.	Pennsylvania.	...	120	1	...	No, scales are located on an auxiliary track.	Dead track.
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	62	200	1	...	Yes, in later installations.	Moder scales have relievin gear.

UESTIONNAIRE. APPENDIX I. (*Continued.*)

arshalling yards for goods trains.

DESIGN. (*Continued.*)						
Advise facilities for car repair, storage of materials and engine shops.	*Is an advance yard desirable or necessary.*	*Advisability of providing an auxiliary or sorting yard.*	*Bad order and repair tracks so located as to require the least amount of engine service.*	*Are compressed air lines installed to charge brake equipment.*	*What provisions have been made to insure prompt movement of road engines.*	*What facilities have you for trains passing through the yard without switching.*
14	15	16	17	18	19	20
Only running and light repair work is done at Brunswick.	No need if tracks are long enough to hold maximum trains.		Yes.	Yes.	Road engines use round house without fouling.	Solid train yard is provided. Do not go into classification yard.
475 car capacity repair and engine storage yard.	Yes, if space is available,	No.	No.	No.	Independent leads round house to west bound yard.	None.
19 car repair tracks. 400 car capacity. Machine shops 30 and 32 stall engine houses.	Yes.	Only with reclassification yard.	Yes.	Yes.	By subway, independent running lead and thoroughfare tracks.	Thoroughfare tracks in each direction located on inside of yard.
Car repair sheds. Repair tracks 104 car capacity. Machine shops and store house.	Would favor an advance yard.	Yes if volume of traffic warrants it.	Conveniently located and cause little lost motion.	Air lines should be installed.	Tracks are so arranged.	Trains passing through are infrequent but would encounter no delay.
Only minor repairs are performed at this yard.	Desirable but not necessary.	Not necessary.	No.	Yes.	Thoroughfare tracks for road engine movement.	Trains do not pass through yard without switching.
District shops and store house of large capacity. Car repair facilities for approximately 20 cars.	Not if departure yard is large enough.	Not practicable in this yard	Yes.	Yard so equipped	Independent running tracks provided and kept clear.	Trains received on assigned yard track and depart after necessary attention.
Car shops equipped to handle all repairs. Engine shops handle light repairs	No.	No.	Yes.	Yes.	Ideal arrangement of tracks.	Thoroughfare tracks are provided if necessary.
Car shop 600 × 1 255 feet. Storage of material for what is required in 48 hours.	Highly desirable.	Desirable.	Yes.	Yes, for eastward movement.	Thoroughfare tracks to desired points.	Outside main tracks.
These features are dependent upon whether the yard is a terminal or en route proposition.	Yes. where traffic is small in lieu of advance yard.	In some instances we have a sorting yard.	Yes.	Departure yards are so equipped.	Thoroughfares and run-around tracks at congested points.	Relay tracks are provided upon which trains are inspected and change of crews and power made.

APPENDIX I. (*Continued.*)

QUESTIONNAIR

Shunting yards : Shunting a

Index number.	DESCRIPTION.			DESIGN.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*What features would you adopt in the design of a new yard to reduce the number of switching movements of locomotives and empty rolling stock.*	*What layouts ar provided for changing, reversing the position of, o detaching engine*
			COLUMN. . .	21	22
1	*Elgin, Joliet & Eastern Railway Company.*	East Joliet.	Illinois.	Should have 75 tracks for receiving yard and additional tracks for classification.	No trains run through yard; al are broken up and reclassified.
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	A hump would materially lessen switching movements of empty rolling stock.	Turntables electrically operat at engine house.
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	Locate engine house, pits, etc. Between the two humps running tracks in either direction from engine house.	Conveniently locat crossovers and slip switches and turntables at engine house.
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	Engine facilities for support of yard and freight train runs located near center of yard.	Turntables at south end, wye at north end and thoroughfare track
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Hump yard. All needed classification tracks of sufficient length to hold full train, etc.	Numerous crossovers conveniently located
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Hump classification. Location of engine house, shops, etc., with reference to receiving and classification yards.	Exclusive engine tracks, running tracks and turntable.

QUESTIONNAIRE

APPENDIX I. (*Continued.*)

marshalling yards for goods trains.

DESIGN. (*Continued.*)				
What kind of ladder tracks would you advise using at the entrance to the classification yard. 23	*Advise what distance track scale is located from summit of hump.* 24	*What speed, miles per hour, would you recommend on track scales for the best motion weighing.* 25	*What rate of grade would you recommend on and over track scales for the best motion weighing.* 26	*Are coaling, ashes pit and engine tracks so located that they can be used in convenient rotation.* 27A
No. 10 Turnouts on account of decreased maintenance.	No hump yard used.	No motion weighing.	No motion weighing.	Yes.
Double spread ladder tracks.	Track scales.	Not located.	In this Yard.	Yes.
No. 8 frog and No. 6 frog angle with the ladder.	No scales used in this yard.	7 miles per hour.	2 °/o grade.	Yes.
Ladders 50 arranged that switches are practically opposite.	120 feet.	3 or 4 miles per hour.	Approximately 1 °/o.	Yes.
Ladder tracks elevated so as to permit free movement of cars into yard.	75 feet to end of scale nearest to summit. (Replies for Coxton yard.)	4 miles per hour. (Replies for Coxton yard.)	0.8 °/o. Minimum : 0.6 °/o. Maximum : 1.0 °/o. (Replies for Coxton yard.)	Yes.
Types indicated on plan, have been found satisfactory	150 feet.	3 to 4 miles per hour.	0.6 to 0.9 °/o.	Yes.

APPENDIX I. (*Continued.*)

QUESTIONNAIR

Shunting yards : Shunting ar

Index number.	DESCRIPTION.			DESIGN.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*What features would you a opt in the design of a new yard to reduce the number of switching movements of locomotives and empty rolling stock.*	*What layouts ar provided for changing, reversing, the position of, or detaching engines*
			COLUMN . .	21	22
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Scales might be located on hump.	Engine yard and turntable.
8	*Erie Railroad Company.*	Port Jervis.	New York.	Straight movement from hump to destination. Thoroughfare tracks not to interfere with engine terminals.	Switches and crossovers locate to meet requirements of existing service
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	Eliminate reverse movements and fix grades so as to do all switching from rear end of trains.	Crossovers and ladder tracks.
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co. Maryland.	Wherever possible avoid back-up by arranging for a continuous headon movement.	Separate track is provided to reac round house without interference.
11	*Southern Pacific Company.*	Roseville.	California.	Three unit yard : inbound, classification and outbound. Main line outside of yard.	A few separate engine leads, two turntables and a wye track.
12	*New York Central Railroad Company.*	Selkirk.	New York.	Avoid back-up movements and duplication of distances, and movements of interference.	Turntables and loop tracks.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	Provide a storage yard for empties to keep them out of main yard and also a hump to reduce switching.	Turntable.

DESIGN. (*Continued.*)				
hat kind of ladder racks would you advise using the entrance to the assification yard 23	*Advise what distance track scale is located from summit of hump.* 24	*What speed, miles per hour, would you recommend on track scales for the best motion weighing.* 25	*What rate of grade would you recommend on and over track scales for the best motion weighing.* 26	*Are coaling, ashes pit and engine tracks so located that they can be used in convenient rotation.* 27A
eatest concentration of switches r manual handling	Scales not on hump.	Scales not on hump.	Scales not on hump.	Yes.
traight No. 8 lead to provide for all classes of ngines and service.	135 feet.	Do not recommend weighing cars in motion.	1.85 %.	Yes.
ntinuous ladder with wide spacing o provide room for switching.	There is no hump in this yard.	About 4 miles per hour.	Six-tenths of one per cent descending grade.	No.
dder tracks arranged n a series in order relieve interference.	50 feet.	3 miles per hour.	Would recommend : 0.6 %. Minimum : 0.5 %. Maximum : 0.75 %.	Yes.
uble switching lead with lead for each section of yard for each engine.	No hump. Scales on independent track between classification and departure yards.	3 to 6 miles per hour.	2 % minimum. Maximum dependent on approach grades.	Use fuel oil.
It is believed types dicated on plan will permit easiest movement of cars.	Scales placed in re-classification yard and not at hump.	4 miles per hour maximum.	Not over approximately 1 per cent.	Yes.
Ladders located o that switch stands uld be on right hand, turnouts to left.	We have no hump.	We have no hump.	We have no hump.	Yes.

APPENDIX I. *(Continued.)*

QUESTIONNAI

Shunting yards : Shunting

Index number.	DESCRIPTION			DESIGN.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*What features would you adopt in the design of a new yard to reduce the number of switching movements of locomotives and empty rolling stock.*	*What layouts provided for changin reversing the position of detaching engi*
			COLUMN . .	21	22
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	Additional classification tracks and a tandem hump if volume of business required such improvements.	None.
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	30 tracks in each yard receiving and departure tracks of length to hold maximum train. Classification yard divided by center ladders. Engine facilities near center of yard.	Open runnin tracks through on outside of y Turntable fo turning engin
16	*Reading Company . .*	St. Clair.	Pennsylvania.	Locate car shops between classification and departure yards. Make south yard 85 car capacity and north yard 50 car capacity.	Road engines r around circle tr
17	*Reading Company . .*	Rutherford.	Pennsylvania.	Elimination of points of contact between road and yard switching. All car movements in direction of their destination.	Ladder and thoroughfa tracks.
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	These features could only be determined after a study of the traffic requirements and physical conditions of location where yard is to be located and built.	Turntable

ESTIONNAIRE APPENDIX I. (*Continued.*)

rshalling yards for goods trains.

DESIGN. (*Continued.*)				
hat kind of ladder tracks would you advise using the entrance to the assification yard. 23	*Advise what distance track scale is located from summit of hump.* 24	*What speed, miles per hour, would you recommend on track scales for the best motion weighing.* 25	*What rate of grade would you recommend on and over track scales for the best motion weighing.* 26	*Are coaling, ashes pit and engine tracks so located that they can be used in convenient rotation.* 27A
Central parallel raight ladders of the same angle as the frog angle.	Track from hump does not lead directly to the track scale.	No motion weighing performed in this yard.	No motion weighing.	No such facilities.
Single ladder for ach 8 or 10 tracks ermits working one gine for each ladder and expedites handling of cars.	No hump yards.	Varies from 1 to 6 miles per hour.	Maximum : 1 °/o. Minimum : 0.6 °/o.	Yes.
Ladder tracks n service entirely satisfactory	Gravity yard, hence no distance from scale to hump.	4 miles per hour.	2 °/o over scale followed by a 3 °/o descending grade.	Yes.
“V” or “W” type.	Do not have these conditions.	Do not have these conditions.	Never operated scale under described conditions.	Yes.
Ladders which equire the shortest distance from hump to the last switch and clearance point.	60 feet.	From one to one and one half miles per hour.	0.8 °/o.	Yes , can be used in proper sequence.

Index number.	DESCRIPTION.			DESIGN.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Can switching engines clean fires, take on coal and water and pass around waiting engines.*	*Can a transf be taken from end of the ya to the other wit interfering with switchin*
			COLUMN. . .	27B	28
1	*Elgin, Joliet & Eastern Railway Company.*	East Joliet.	Illinois.	Yes.	Yes.
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	Yes.	Yes.
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	Yes.	Yes.
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	No.	Yes.
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Yes.	Yes.
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Engine facilities arranged as to result in a minimum delay.	Yes.
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Yes.	Yes.
8	*Erie Railroad Company.*	Port Jervis.	New York.	Yes.	Yes.
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	No.	Yes, by using t running track and main track

ESTIONNAIRE. APPENDIX I. (*Continued.*)

shalling yards for goods trains.

DESIGN. (*Continued.*)				
your crossovers so arranged to give the least interference switching or can dditional ones put in to secure these results.	*Are the caboose tracks so located that cabooses may be handled with the least amount of switching.*	*Advise character of and give general description of coaling station, ashes pits and engine houses.*	*Yard lighting advise kind and spacing.*	*Describe telephone and telegraph facilities.*
29	30	31	32	33
Yes.	Yes.	Concrete coaling Station Round house : 31 stalls. Round house : 17 stalls. Locomot. : shop 152'×577'. Car shop : 300'×500' Deep water ashes pits.	Switch lamps and arc lights. Flood lights at the terminal.	Bell telephone. Telegraph lines to yard master and agent's office.
sent crossovers are sufficient.	Yes.	Timber coaling station : 360 t. capacity. Ashes pit : 200 ft long. Brick engine house : 32 stalls. Brick power house.	Series of tungsten lamps 600 candle power spaced. 600 feet apart.	Dial system of telephones and special telephone lines.
e arrangement the crossovers e satisfactory.	Yes.	Frame coaling station : 1260 ton capacity. Ashes pits water cooled : 200 feet long. Brick engine house : 41 stalls.	600 candle power tungsten. Lamps 30 to 35 feet high, spaced 200 and 300 feet apart.	26 telephones Private circuit to air cabins. Auxiliary service between round. House and yard.
Yes.	Completion of all units will practically accomplish this.	Elevator type coaling station. Crane ashes pit : 44 and 30 stalls. Engine house.	500 watt flood ligths spaced 150 feet apart.	Telegraph not provided. General telephone system connecting all offices.
es, with one itional crossover west end of east bound yard.	Yes.	Concrete coaling station : 1200 tons capacity. Ashes pit : 348 ft. long. Concrete engine house : 31 stalls.	This yard is dark. Flood lighting is recommended.	Telephone and telegraph facilities very good to all parts of the yard.
sent crossovers e sufficient and are arranged atisfactorily.	Yes, caboose tracks have connections at each end.	Link belt type coaling station. Ash pit double track ; 30 stall. Engine house.	Electric flood lights placed on high poles.	All offices, yards, etc., are connected by telephone and telegraph.
Yes.	Yes.	...	Arc lamps and search lights.	All offices, yards, etc., connected by telephone.
Yes.	Yes.	Concrete gravity pockets. Ash pits. Wet type. Engine house : 32 stalls.	Flood lighting with about 10 lights erected on tower.	Offices, engine house towers, etc. connected by telephone ; no telegraph.
Sufficient ossovers have een provided.	Yes.	Timber coaling station. Concrete ashes pits. 12 stall brick. Engine house. 4 stalls. French house.	Yard not lighted.	All offices and towers connected by telephone.

Shunting yards : Shunting

Index number.	DESCRIPTION.			DESIGN.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Can switching engines clean fires, take on coal and water and pass around waiting engines.*	*Can a transfe be taken from c end of the yar to the other with interfering with switchin*
			COLUMN. . .	27B	28
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	No.	Yes.
11	*Southern Pacific Company.*	Roseville.	California.	Use fuel oil.	No.
12	*New York Central Railroad Company.*	Selkirk.	New York.	Yes.	Yes.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	Switch engines are well taken care of on separate tracks.	This yard is s arranged.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	No such facilities.	Yes.
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	Yes.	No.
16	*Reading Company . .*	St. Clair.	Pennsylvania.	Yes.	Yes.
17	*Reading Company . .*	Rutherford.	Pennsylvania.	Yes.	Yes, over thoroughfa tracks.
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	Yes.	Thoroughfare tracks are provi in both directio

shalling yards for goods trains

DESIGN. (*Continued.*)				
your crossovers so arranged to give the least interference switching or can dditional ones out in to secure these results.	*Are the caboose tracks so located that cabooses may be handled with the least amount of switching.*	*Advise character of and give general description of coaling station, ashes pits and engine houses.*	*Yard lighting advise kind and spacing.*	*Describe telephone and telegraph facilities.*
29	30	31	32	33
ew additional sovers might be in to facilitate novements.	Yes.	Frame coaling station Ashes pits. With depressed track. Engine house : 19 stalls.	Arc lights spaced about 200 feet apart.	Central switch board with lines to all points in addition to side wires.
o, additional ssovers can be put in.	Yes.	Oil fuel used : 55 000 barrel storage tank. Two 32 stall engine houses. No ashes pits.	No Lighting facilities.	Telephones connected to central switch board.
Yes.	Yes.	Coaling station 1 200 ton capacity. Ashes pits are water type. Engine house : 30 stalls. Engine house : 32 stalls. Machine shops, etc.	1 000 watt flood lights on poles 75 feet high. Spaced approximately 1 500 feet apart.	Telephone exchange to all Departments in the yard. Railroad long distance lines to division head-quarters. etc.
ssovers seem e well located.	Caboose tracks may be entered at either end.	Mechanical coal plant. Tracks for oil burning engines. Cinder conveyors and ice plant.	We have no lighting system in this yard.	Complete telephone and telegraph to all points. Bell telephone for public service.
Additional ssovers would not help. mum handling rranged for.	No.	No such facilities at this yard.	Electric lights spaced about 300 feet apart.	Two distant and two local telegraph circuits. Two train dispatching telephone message circuits connecting all points.
except in one r two minor locations.	Yes.	500 ton conveyor type coal chute. Depressed type ash pit. 80 and 107 foot brick. Round House. 90 foot turntable.	No lighting except at shops and ice house. One flood light on coal chute lighting the ash pit and turntable.	Telegraph facilities at yard office and store house. Automatic telephone service connecting all points and departments.
no additional crossovers required.	Yes.	Concrete coaling station; crane and bucket ash pits. 52 stall engine house.	Electric lights in parallel lines 100 feet apart Poles : 130 feet apart Staggered.	All facilities connected by private telephone exchange.
no additional crossovers required.	Yes.	Gravity wooden coaling station; water filled ash pits : 19 stall engine house. Electric turntable.	Flood system 1 000 watt lamps : 281 candle power on posts 60 feet high and 480 feet apart.	Telephone dispatch circuit, telephone Switch board service and 2 auxiliary magnetic telephone lines.
s, others are dded as the ssity becomes apparent.	Yes.	Concrete mechanical coaling station; ashes are handled by overhead crane.	Ladders are flood lighted. Yard-series arcs.	All departments are connected by telephone.

QUESTIONNAI

Shunting yards : Shunting

Index number.	DESCRIPTION.			OPERATION.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*What method do you employ to turn equipment.*	*Is there any unus feature in the yar adopted to reduc the number of movements of rolling stock*
			COLUMN. . .	1	2
1	*Elgin, Joliet & Eastern Railway Company.*	East Joliet.	Illinois.	Turntables.	No.
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	Turntable.	Receiving yard is actually the hu yard.
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	Two turntables at the engine house.	No.
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	Turntables and wye tracks.	Wye track at en opposite turntab Additional thorou fare and runnin tracks are provid
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Electric operated turntable.	No.
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Turntables.	Classification of c over the humps
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Turntable.	No.
8	*Erie Railroad Company.*	Port Jervis.	New York.	Turntable.	Hump yard to exp classification and advance ya to relieve same
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	Turntable and wye track.	No.
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	Turntable.	Principal featu are general design solid train yar

rshalling yards for goods trains.

OPERATION. (*Continued.*)

s the shunting of mpty trains done ith road engines or hunting engines.	*Have you adopted any special arrangement in making up trains to reduce shunting.*	*Have you any special rrangements to report to reduce the movement of engines and empty rolling stock.*	*Advise how switches are operated and how signalled.*
3	4	5	6
Switch engines.	No.	No.	Hand operated.
Shunting engines	None.	Present layout satisfactory.	Hand operated switch lamps are used Semaphores and sirens.
Shunting engines.	No.	No.	Hand operated. The switch tender is furnished with a classification ticket.
Yard engines.	Effort is made to classify all cars for one train on two adjacent tracks.	General flexibility to and from engine house through receiving and departure yards.	Electro-pneumatic switches, semaphores, air sirens, and switch targets and lamps.
Shunting engines.	Yes, cars placed in station and destination yard order.	No.	Hand operated switches in yard. Interlocking on outlet east bound and inlet west bound.
witching engines.	Classify cars so as to have a minimum amount of switching.	Varying conditions are studied closely and constant supervision insures the maximum economy.	Hand operated and signalled.
Yard engines.	No.	No.	Manually operated excepting at junction interlocking plants.
Shunting engines.	Trains are made up with the idea of not breaking up at intermediate points more than necessary.		Hand thrown except at both ends of yards which are controlled by interlocking plants.
Switching engines.	A switch list is used showing tracks on which cars are to be placed.	No.	Hand operated. Switch targets and lamps are used.
Switching engines.	Trains classified so as to minimize switching at destinations.	No; other than design of yard and handling main trackers.	Air whistle signals. Switches east bound operated by push button. West bound are hand operated.

APPENDIX I. (*Continued.*)

QUESTIONNAIR

Shunting yards : Shunting a

Index number.	DESCRIPTION.			OPERATION.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*What method do you employ to turn equipment.*	*Is there any unusu feature in the yard adopted to reduce the number of movements of rolling stock.*
			COLUMN. . .	1	2
11	*Southern Pacific Company.*	Roseville.	California.	Two turntables and one wye.	Independent lead fo engines to and fro engine house whic eliminates the use o yard leads.
12	*New York Central Railroad Company.*	Selkirk.	New York.	Two turntables and loop track.	Loop track ordinari not provided.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	Turntable.	No.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	Wye track.	Yard designed so that there is generally only one handling by yard engines.
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	Turntable.	No.
16	*Reading Company* . .	St. Clair.	Pennsylvania	Circle track and 85 feet electric driven turntable.	None.
17	*Reading Company* . .	Rutherford.	Pennsylvania.	Two electrically operated turntables.	Round house centrally located wit independent thoroughfares to an from round house.
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	Turntable.	...

arshalling yards for goods trains.

OPERATION. (*Continued.*)			
s the shunting of mpty trains done vith road engines or hunting engines.	*Have you adopted any special arrangement in making up trains to reduce shunting.*	*Have you any special arrangements to report to reduce the movement of engines and empty rolling stock.*	*Advise how switches are operated and how signalled.*
3	4	5	6
Shunting engines.	Yes, by blocking trains so that on arrival in yard switching will be reduced to a minimum.	No.	By hand.
Switch engines used.	Small reclassification yards for handling cars in station. Order provided adjacent to out bound ends of classification yards.		Leads from hump controlled by power operated switches; other switches generally hand operated.
Switch engines.	No.	No.	Switches are hand operated and signalled by hand and lantern.
Hump engines.	Main track exchange of crews here on through trains, relieving yard of handling cars for district terminals.	Thoroughfare tracks for movement of engines so as not to interfere with movement of other engines in yard territory.	By hand. Throw switches within yard, interlocking plants at ends of yard.
ll yard switching is done by hunting engines.	Through trains for distant destinations. Classify other trains in station order.	No.	By hand. Switch stands equipped with targets and lamps.
Shunting engines northward ravity southward.	No.	None.	All switches thrown by hand switch targets only.
Handled by hump engines.	Yes, by classification into groups on short tracks.	No.	Electric pneumatic push button system.
Yard engine.	...	...	Electric, pneumatic.

APPENDIX I. (*Continued.*) QUESTIONNAIR

Shunting yards : Shunting a

	DESCRIPTION.			OPERATION.	
Index number.	**Name of railroad.**	**Name of yard.**	**Location of yard.**	*Advise method of keeping a record of car movements.*	*Can you quicker movement of trai through the thro of the yard by putting on switc tenders at these points.*
			COLUMN. . .	7	8
1	*Elgin, Joliet & Eastern Railway Co.*	East Joliet.	Illinois.	Yard clerks reporting to the agent.	Switch tenders us at both ends of yar
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	Book record kept of arrival, train reference, car number etc., by yard masters off.	Switch tenders ar used when and where required.
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	Tickets marked with numerals giving car and track number.	Our yards do not require such additional tenders
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	Car record and humping list shows number of car, track, rider, etc.	No, switchmen on duty 24 hours.
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Report of each train moved, car numbers and initials.	No, switch tender employed where th can be worked to advantage.
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Report of time received, when humped, car rider, and daily check, etc.	Switch tenders ar stationed at such places and for thi purpose.
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Complete record of train, initial, number and content of car is prepared.	Switch tenders ar used wherever necessary.
8	*Erie Railroad Company.*	Port Jervis.	New York.	Car record made from train lists of trains arriving and departing.	Switch tenders ar employed and locat at busy points in yard.
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	Book records kept showing lading, arrival, departure and train handling same.	Yes, switch tende are used during th busy season.

ESTIONNAIRE.

APPENDIX 1. (*Continued.*)

rshalling yards for goods trains.

OPERATION. (*Continued.*)				
uld you facilitate weighing by hanging or by ldition of other connections the scale track.	*Can the engine be taken to the round house, then to an outbound train without materially interfering with switching.*	*If you are operating a hump, can you change grades of the hump and facilitate switching.*	*Advise method of classifying cars: do you classify with regard to station, track and industry destination.*	*If car riders are employed, what rule or formula do you use to determine how many are required.*
9	10	11	12	13
No.	Yes.	Not a hump yard.	Placed in station order.	3 riders at each end of yard.
Track scales not used.	Yes.	Yes by a slight descending grade approaching hump to help switch engine.	Yes.	We have determined the average number of car rides per man per day.
weighing done.	Road engines do not materially interfere with switching.	Yard masters would not consider any change in grades	Classified with regard to station destination.	Number of riders is determined from advance information
No.	Yes.	Low summer and high winter humps have been established on parallel tracks.	Yes, to station, industry and track destination.	Average 50 or more cars per rider.
No, as scale is cated on hump der (Coxton yard).	Yes, on west bound, no, on east bound.	Increase grade in winter.	Classified with regard to destination according to commodities.	Determined by average cuts and time required for return of riders.
esent location of les results in no interference.	Engines pass to and from engine house without interfering with switching.	Hump and scales not arranged to permit changes in grade readily being made.	Outbound to destination, inbound to industry or locality.	Men at this work are employed as needed. No fixed rule to determine number.
sent arrangement ufficient for our present needs.	Yes.	No.	Road movements to stations and routes. For transfer to base yards.	No rule or formula.
No.	Yes.	Present grades adequate.	Classify as to station and when conditions warrant classify as to industry.	A check is maintained of trains to arrive and number of car riders determined.
o, only a small tion of the cars assing through are weighed.	Yes.	No hump in this yard.	Classify as to destination.	Riders or droppers not employed.

APPENDIX I. (*Continued.*) QUESTIONNAI

Shunting yards : Shunting

Index number.	DESCRIPTION.			OPERATION.	
	Name of railroad.	**Name of yard.**	**Location of yard.**	*Advise method of keeping a record of car movements.*	*Can you quicke movement of tra through the thro of the yard by putting on swi tenders at thes points.*
			COLUMN. . .	7	8
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	Use cutting lists yard conductor making cuts at hump. Train lists for outgoing.	Yes this has be done at Brunswi
11	*Southern Pacific Company.*	Roseville.	California.	Complete check of yard made twice in 24 hours. Records of car movements by yard clerks.	Yes, switch tend are maintained both ends of ya during busy seas
12	*New York Central Railroad Company.*	Selkirk.	New York.	Record is kept of cars moving out by consist report of each train.	Yes.
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	Record is kept of car number, initial kind of car, seals, contents and disposition to be made	We do hasten t movements of ca by using switc tenders.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	Record book indexed for last two figures of car No. blocked into squares for next preceding No.	No. This situati is protected by interlockin switches handl from the towe
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	Index record of all cars handled through yard. Switch lists and wheel reports on file.	Have switch tend at these points this purpose.
16	*Reading Company* . .	St. Clair.	Pennsylvania.	Shipping bill made by coal clerk at time car is weighed.	Yes.
17	*Reading Company* . .	Rutherford.	Pennsylvania.	Record of way bill car ticket on inbound movement. Record of initial, number, contents and destination outbound.	Such switch tend are stationed in y where require
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	Complete car record system.	...

ESTIONNAIRE.

shalling yards for goods trains.

OPERATION. (*Continued.*)

uld you facilitate weighing by hanging or by ldition of other connections the scale track.	*Can the engine be taken to the round house, then to an outbound train without materially interfering with switching.*	*If you are operating a hump, can you change grades of the hump and facilitate switching.*	*Advise method of classifying cars: do you classify with regard to station, track and industry destination.*	*If car riders are employed, what rule or formula do you use to determine how many are required.*
9	10	11	12	13
No.	Yes.	Yes. Hump is raised in winter by raising track.	Yes, as far as possible. Attempt to classify at least for locality.	Average one car rider for every 80 cars.
Yes.	Outgoing engines must use switching leads used by yard engines which at times interferes with the work.	Not operating a hump.	Cars are classified with regard to station.	...
cales located in assification yard.	Yes.	Yes.	Classified with due regard to station order.	Number of car riders determined by experience.
nere is no inter- ence that would rrant changes in onnection with scales.	Yes.	We have no hump.	We classify trains in set out order.	We have no riders.
No.	Yes.	Grade of hump is so fixed that highest possible efficiency can be obtained.	No, classify for terminals only.	Varies with number of trains handled per day. Trains moving toward yard reported in advance of arrival.
lo. Scales now located and nnected to best advantage.	No.	No hump yards on system.	Yes.	Car riders not used.
No.	Yes.	Not operating a hump.	Yes, to station, industry and track destination.	One man can make 35 to 40 runs over scale per 8 hour day.
es, by removing e from its present tion and placing it on . I shop track.	Yes.	Humps are constructed for normal winter conditions.	Yes, to station and industry destinations.	By having advance report of all cars expected, can then determine force required.
...	...	...	...	By business on hand and reported moving.

APPENDIX I. (*Continued.*) QUESTIONNAI

Shunting yards : Shunting

	DESCRIPTION.			OPERATION.		
Index number.	**Name of railroad.**	**Name of yard.**	**Location of yard.**	*What provision is made to bring back car riders from end of yard. If rider track is provided give location and method of operation.*	*Number of cars ha in each directi in a period of 24 h*	
					Loaded.	*Em*
			COLUMN. . .	13	14A	
1	*Elgin, Joliet & Eastern Railway Co.*	East Joliet.	Illinois.	None.	2000 2500	We Ea
2	*Delaware, Lackawanna & Western Railroad Company.*	Secaucus.	New Jersey.	No provision is made.	E. B. 700-1000 W. B. 300-400	W. 400-
3	*Delaware, Lackawanna & Western Railroad Company.*	Keyser Valley. Hump Yard.	Scranton. Pennsylvania.	Electrically driven refitted caboose on track in centre of yard.	800 for both direc in 8 hours.	
4	*New York, New Haven & Hartford Railroad Company.*	Cedar Hill.	Connecticut.	Gasoline operated speeder cars; a special speeder track is provided.	E. B. 1200 W. B. 600	E. B. W. B
5	*Lehigh Valley Railroad Company.*	Manchester.	New York.	Gasoline motor. Independent track located well in center of yard.	1700	
6	*Chicago, Milwaukee & St. Paul Railway Company.*	Bensenville.	Illinois.	Gasoline motor. Motor car tracks on outside also near center of classification yards.	About 1300 both and empties ea and west bour per 24 hour per	
7	*Canadian Pacific Railway Company.*	North Transcona.	Manitoba-Canada.	Small switch engine handles flat car with side running boards.	W. B. 150 E. B. 1 130	W. B E. B
8	*Erie Railroad Company.*	Port Jervis.	New York.	Car riders walk back short lead and there is no rider track provided.	E. B. 990 W. B. 283	E. B W.

rshalling yards for goods trains.

OPERATION. (*Continued.*)						
al number engines rned in a period 24 hours.	*Total number of tons of coal loaded on engines each day.*		*Total number of yard engines employed.*	*Total number of yard crews employed.*	*Daily average number of cars transferred on account of defects.*
	Anthracite.	*Bituminous.*			
14B	14C		14D	14E	14F
55	...	388	18	18	5
55	...	370	16	16	3
75	750 tons of coal		9	9	No transfers made in this yard.
110	800 tons.		25	An average of 50 shifts are employed.	5
50	...	400	15	15	Very few, about one car per month.
75	...	400	32	40	From 2 to 3 cars per day.
Average 146	...	170	35	42	3
74	...	599	20	20	Average 1 per day.

Shunting yards : Shunting a

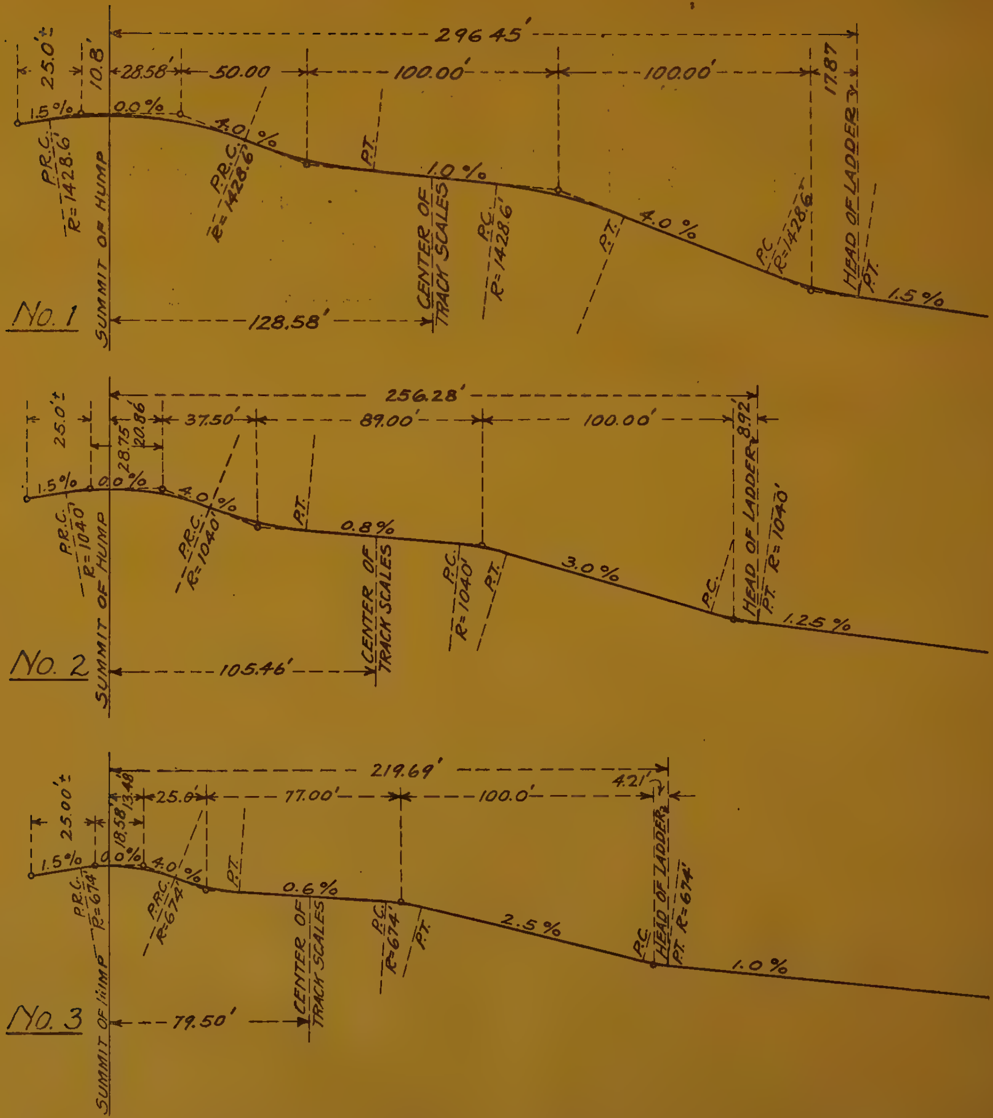
	DESCRIPTION.			OPERATION.		
Index number.	Name of railroad.	Name of yard.	Location of yard.	*What provision is made to bring bac car riders from end of yard. If rider track is provided give location and method of operation.*	*Number of cars han in each directio in a period of 24 ho*	
					Loaded.	*Emp*
			COLUMN. . .	13	14A	
9	*Bessemer & Lake Erie Railroad Company.*	Albion.	Erie Co., Pa.	...	N. B. 448 S. B. 828	N. B.
10	*Baltimore & Ohio Railroad Company.*	Brunswick.	Frederick Co., Maryland.	Motor cars with track in middle of yard.	E. B. 1 200 W. B. 500	E. B. W. B.
11	*Southern Pacific Company.*	Roseville.	California.	...	E. B. 705 W. B. 745	E. B. W. B.
12	*New York Central Railroad Company.*	Selkirk.	New York	Two rider tracks in each classification yard. Gasoline motor cars.	E. B. 3 000 W. B. 1 000	... W. B. 2
13	*The Atchison, Topeka & Santa Fe Railway Company.*	Argentine.	Kansas.	We have no riders.	W. B. 401 E. B. 1 111	W. B. E. B.
14	*The Central Railroad Company of New Jersey.*	Allentown.	Pennsylvania.	No rider track, men walk; the distance is about 300 yards.	East 2 006 West 2 006	
15	*The Chicago, Rock Island & Pacific Railway Company.*	Silvis.	Illinois.	Car riders not used.	1 200 to 1 500	
16	*Reading Company . .*	St. Clair.	Pennsylvania.	By gasoline driven car on independent track parallel with yard.	1 000 North 1 000 South	
17	*Reading Company . .*	Rutherford.	Pennsylvania.	By gasoline motor car on track centrally located for east bound hump. Walk back on west bound hump.	1 800 E. 1 800 W. } Norm 5 407 maximum	
18	*Pennsylvania Railroad System.*	Enola.	Pennsylvania.	On switch engines, with poling cars, or gas motor cars.	E. B. 2 063 W. B. 2 267	

ESTIONNAIRE APPENDIX I. (*Continued.*)

rshalling yards for goods trains.

OPERATION. (*Continued.*)					
al number engines ned in a period 24 hours.	*Total number of tons of coal loaded on engines each day.*		*Total number of yard engines employed.*	*Total number of yard crews employed.*	*Daily average number of cars transferred on account of defects.*
	Anthracite.	*Bituminous.*			
14B	14C		14D	14E	14F
Average 30	...	Average 288	Average 5	Average 10	One car every 2 days.
80	...	850	16	34	8
23	None.	None.	23	23	1
140	1100 tons		20	20	5
70	...	200	25	28	2 6
25	200 tons daily for yard engines only.		5	15	2
45 to 55	..	350	10	21	8 to 10
0 average	110	280	10	15	2
5 average	1000 tons		9 24 hours each.	19 8 hours each.	4
...	...	178	47	28	...

APPENDIX II (figs. 1 to 10).



The above are for humps with track scales No. 1, for cold climates, No. 2, for moderate climates, and No. 3, for warm climates.

SCALES	Horizontal	2/3 inch = 50 feet.
	Vertical.	2/3 — = 5 —

Fig. 1. — Recommended hump profiles for mixed traffic of merchandise and empties.

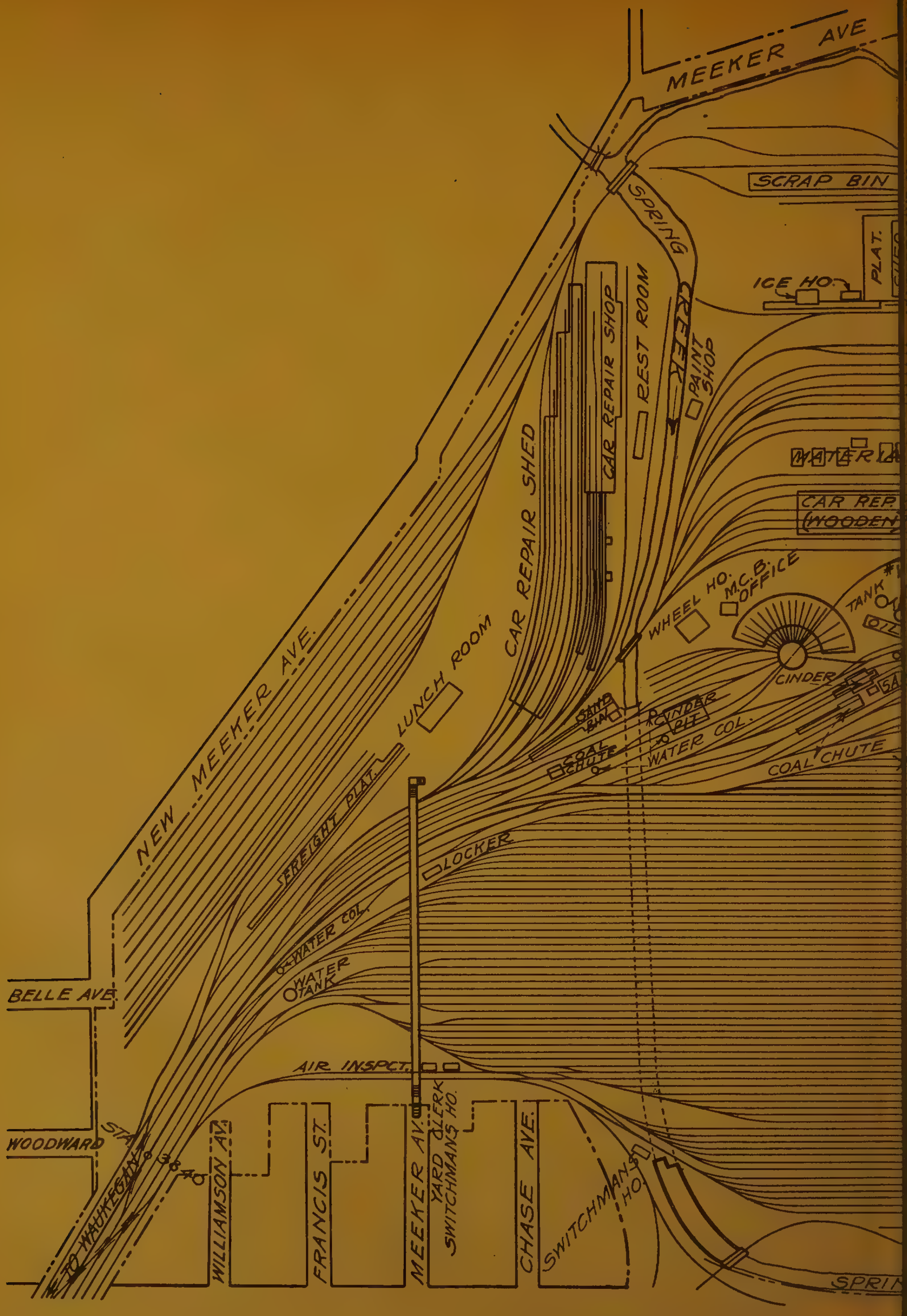
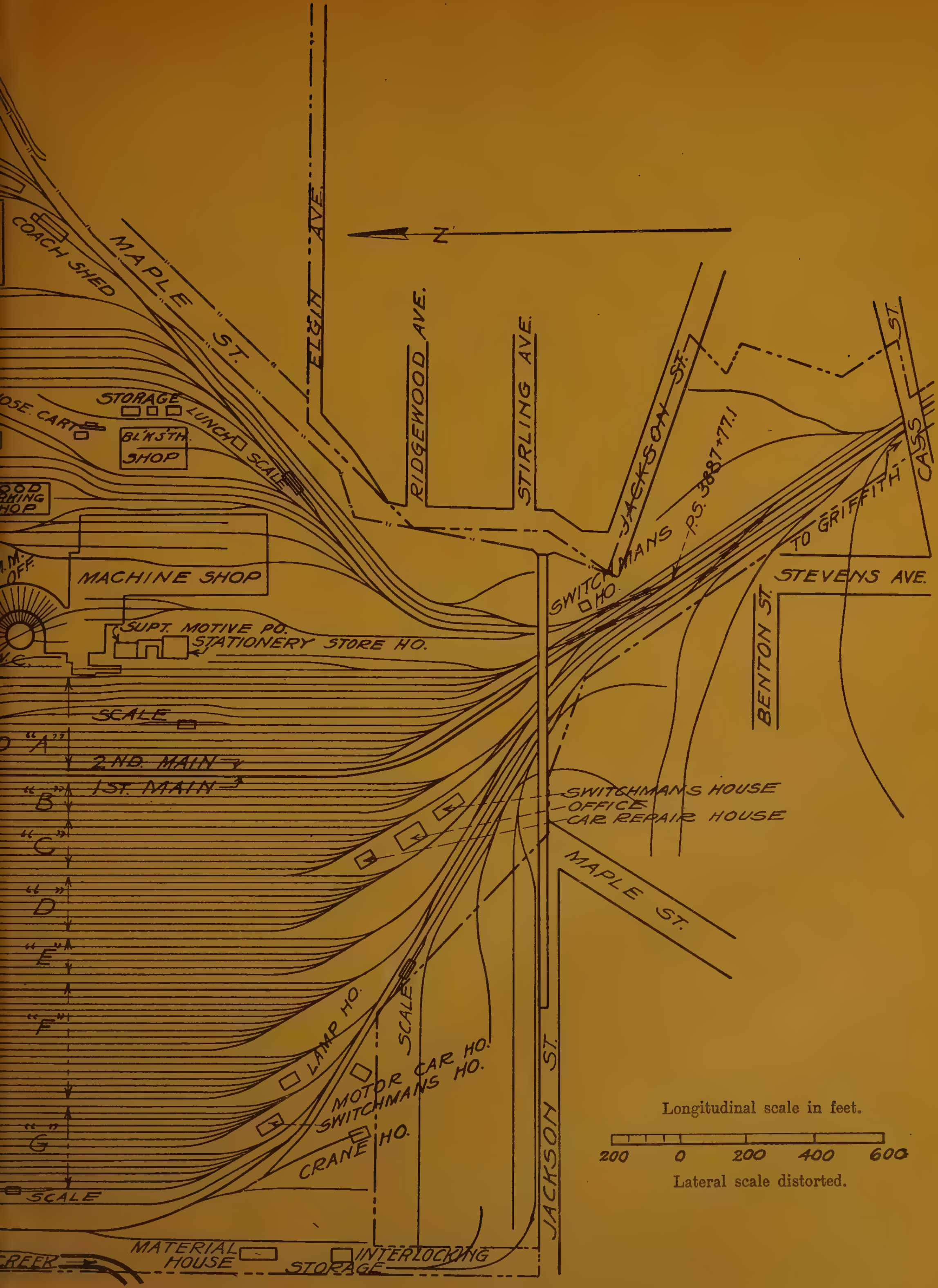


Fig. 2. — Elgin, Joliet & Eastern Railway



pany. — Plan of East Joliet yards, Joliet, Illinois.

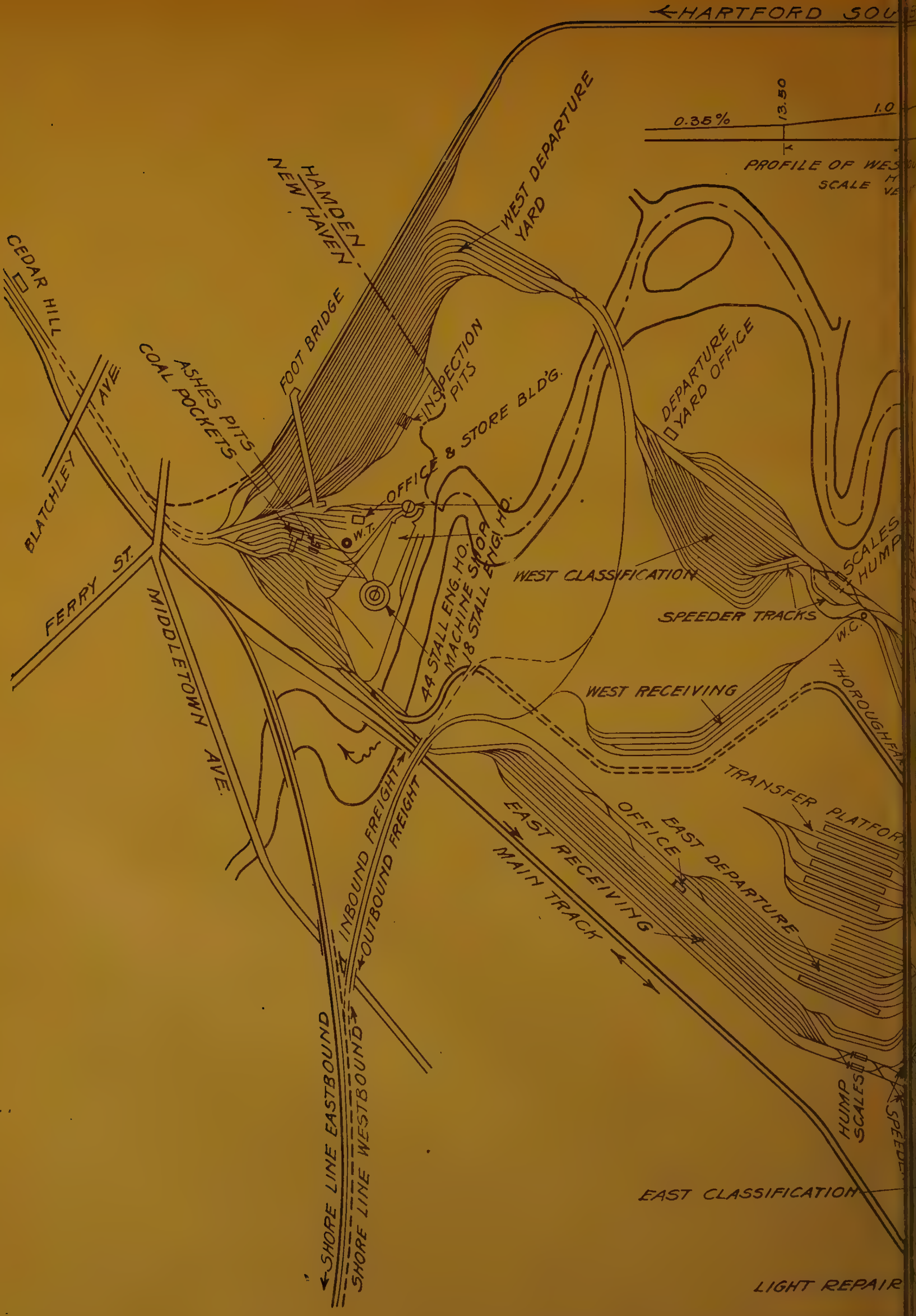
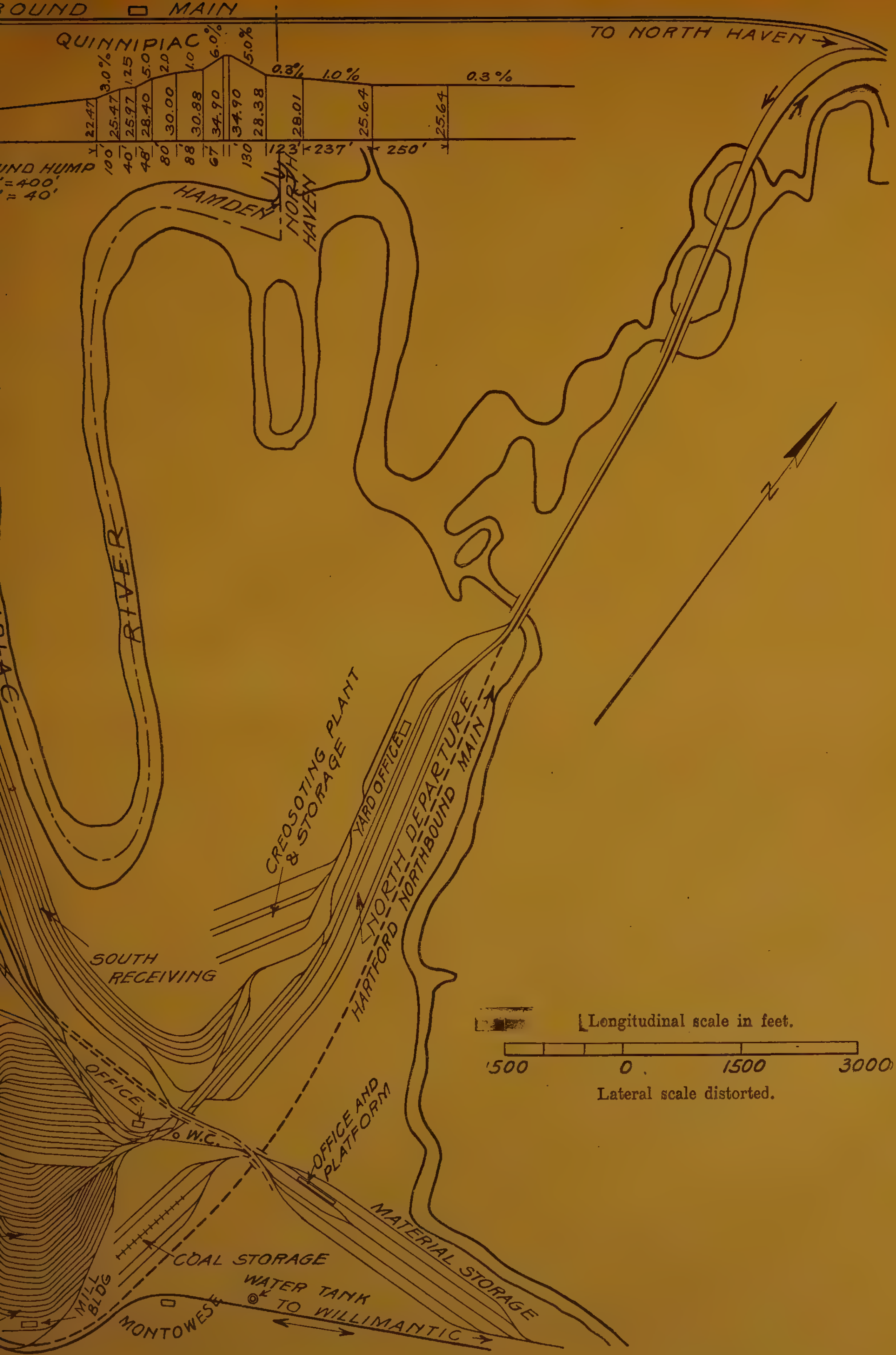


Fig. 3. — New York, New Haven & Hartford Railroad



Plan of Cedar Hill yard, Cedar Hill, Connecticut.

X—14

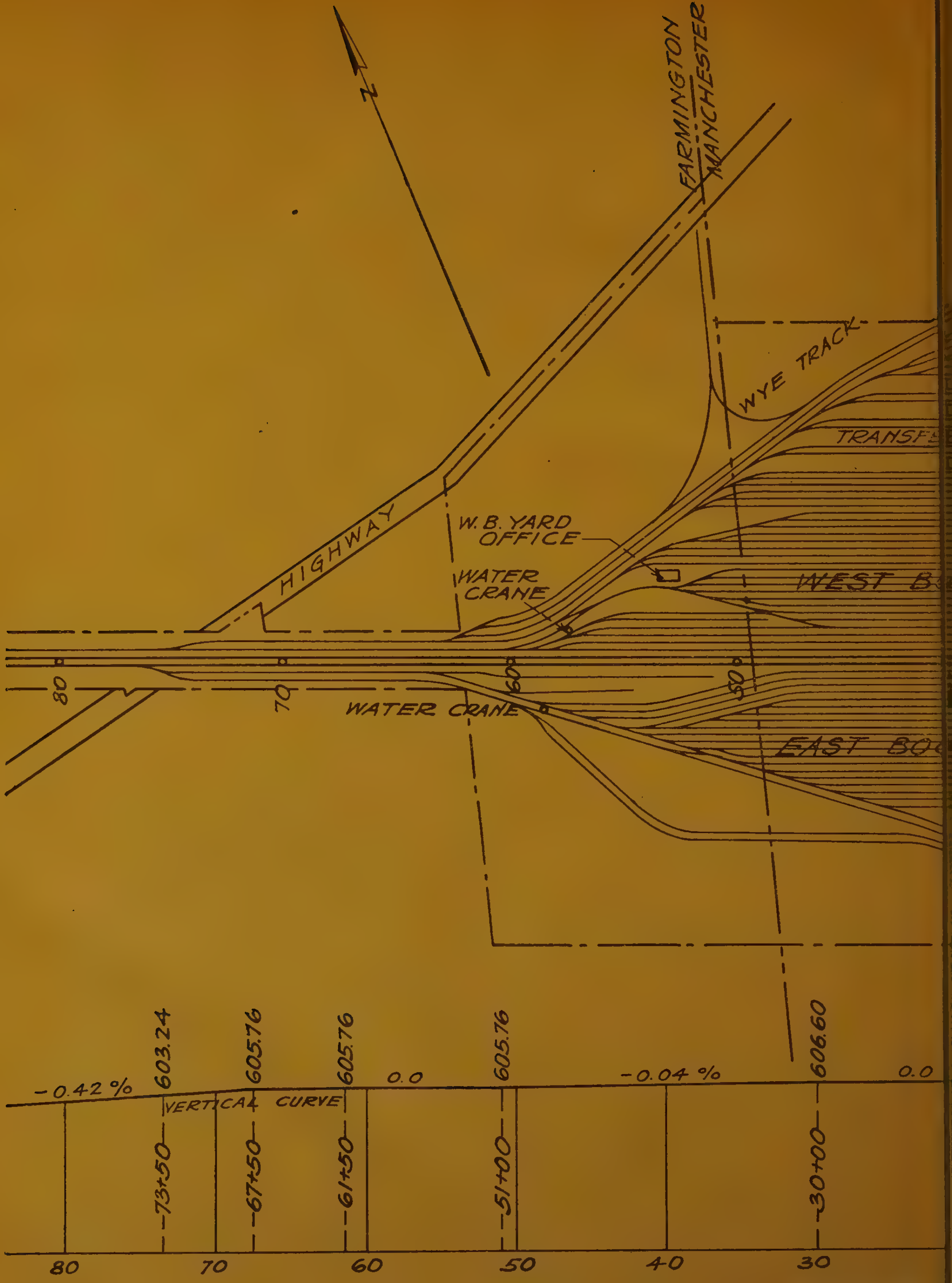
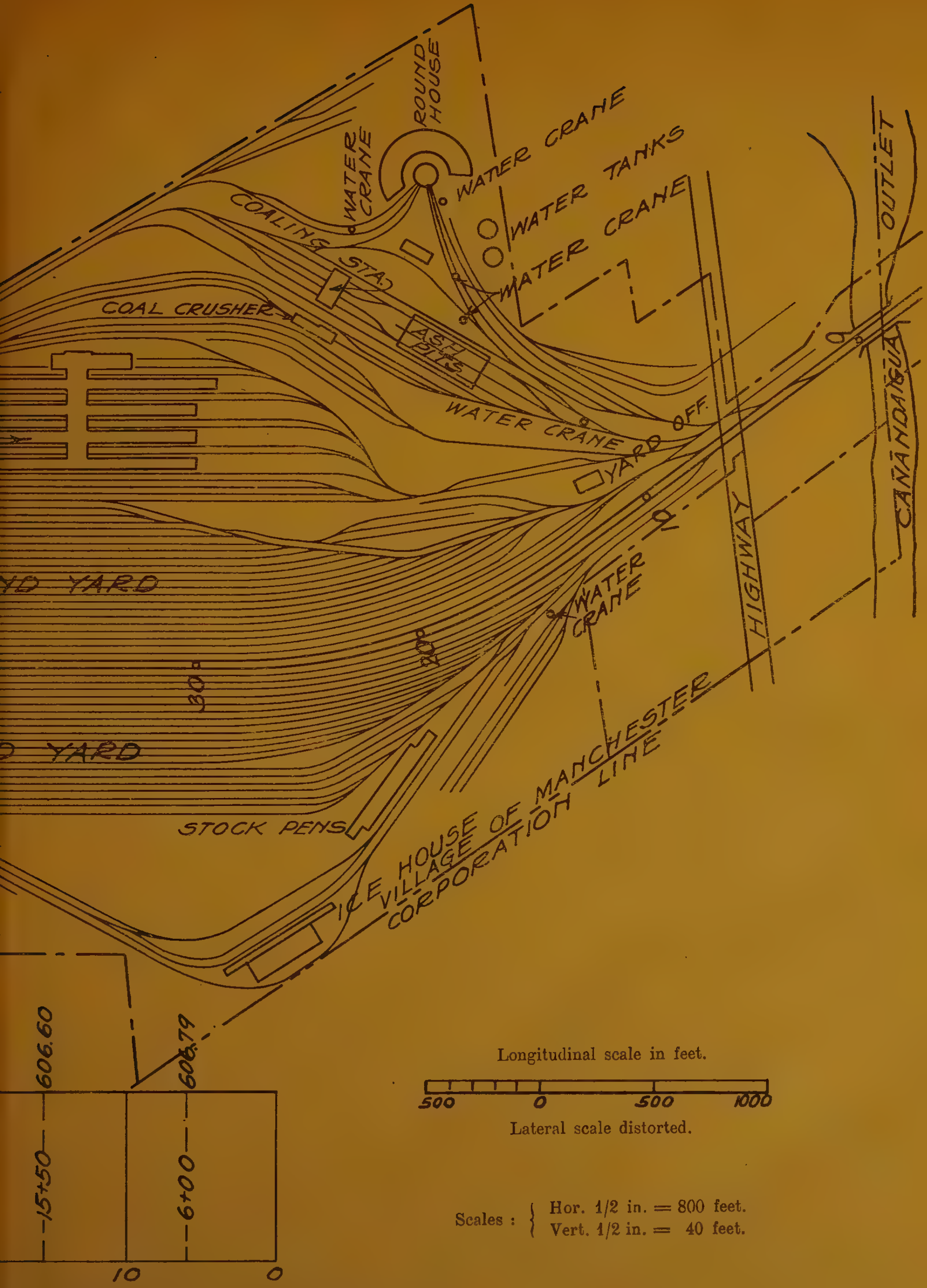


Fig. 4. — Lehigh Valley Railroad Company.

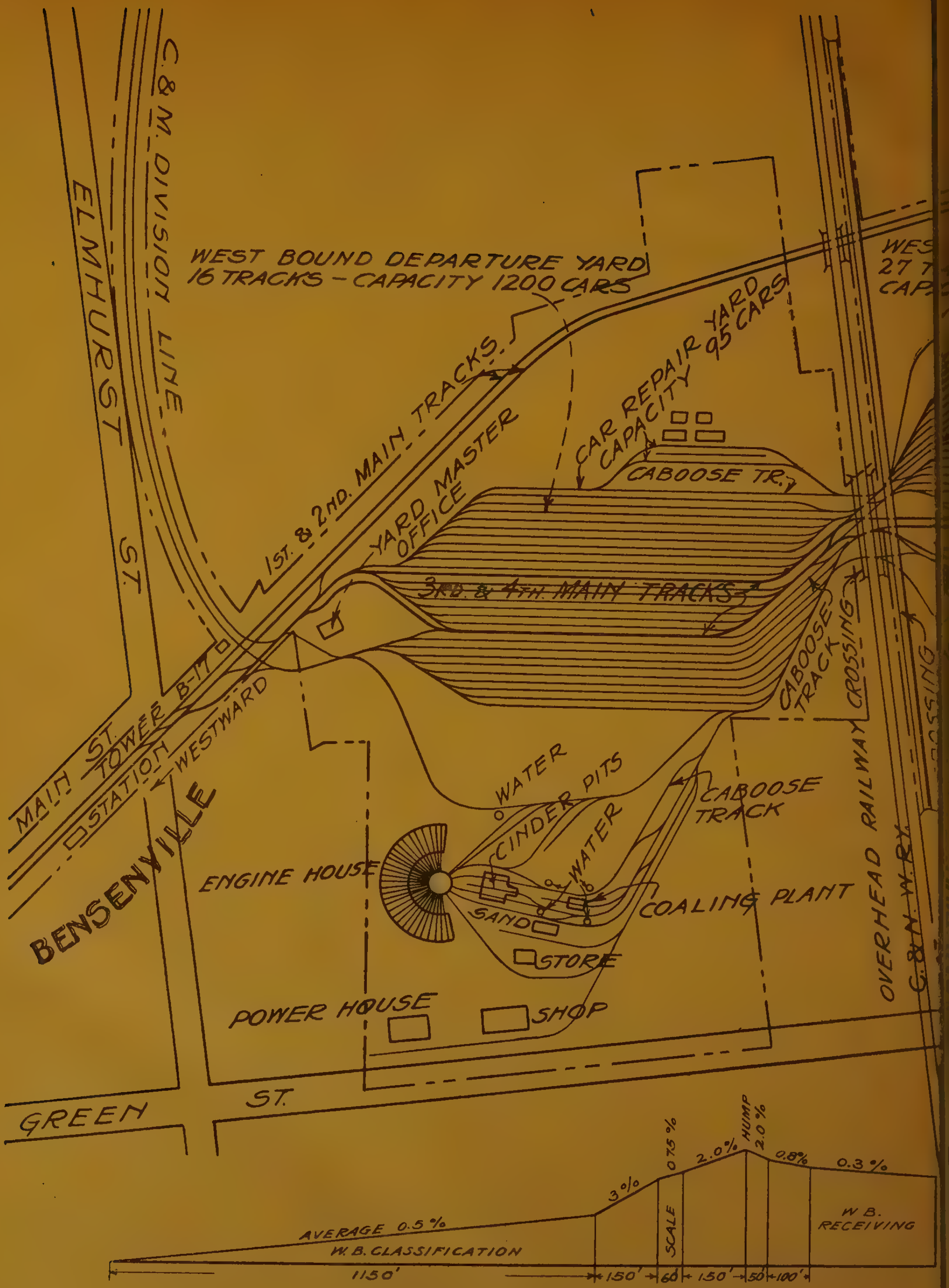


Longitudinal scale in feet.

Lateral scale distorted.

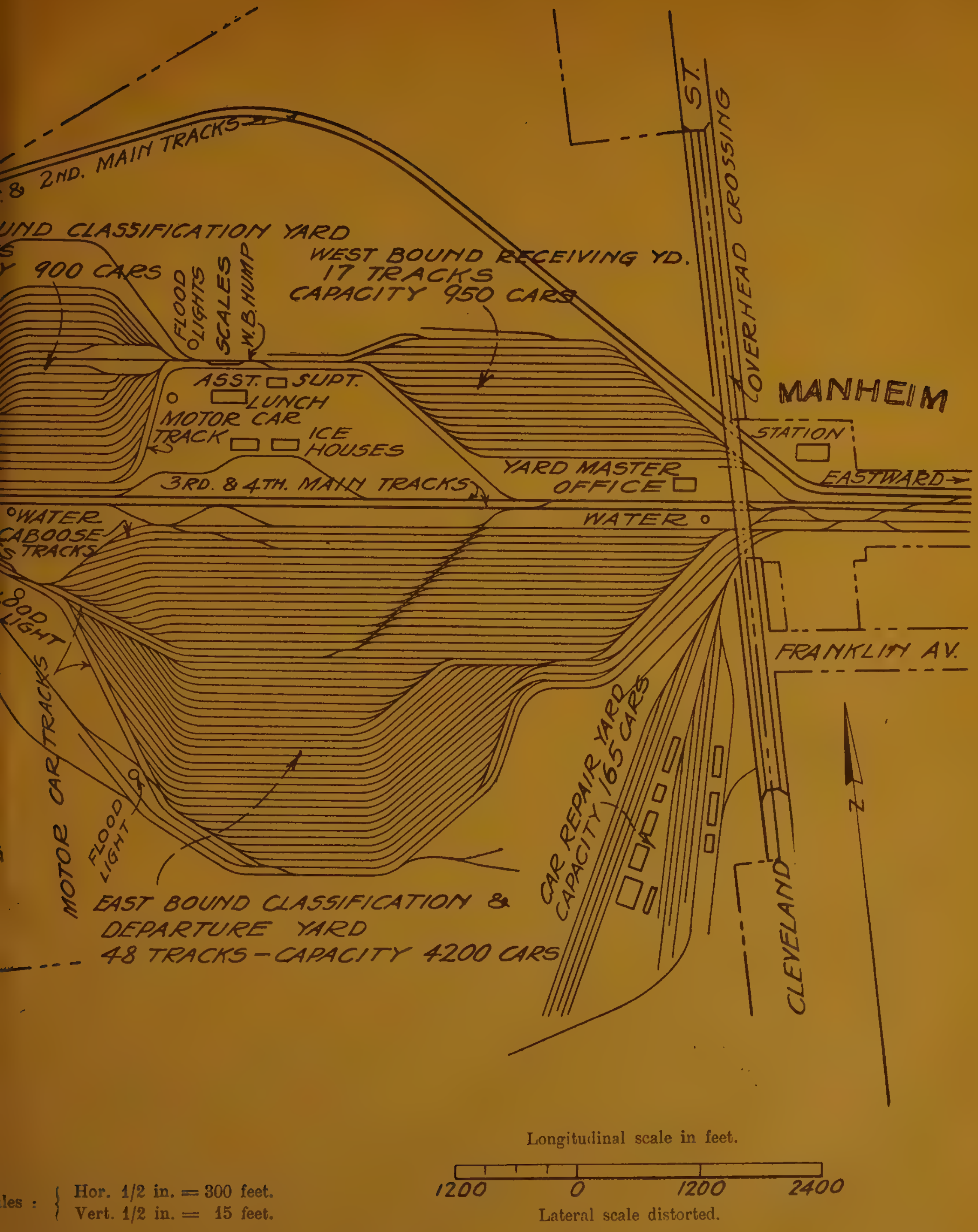
Scales : { Hor. 1/2 in. = 800 feet.
Vert. 1/2 in. = 40 feet.

lan of Manchester yard, Manchester, N. Y.



Profile of west bound hump. East bound hump similar.

Fig. 5. — Chicago, Milwaukee & St. Paul Railwa



les : { Hor. 1/2 in. = 300 feet.
Vert. 1/2 in. = 15 feet.

any. — Plan of Bensenville yard, Bensenville, Illinois.

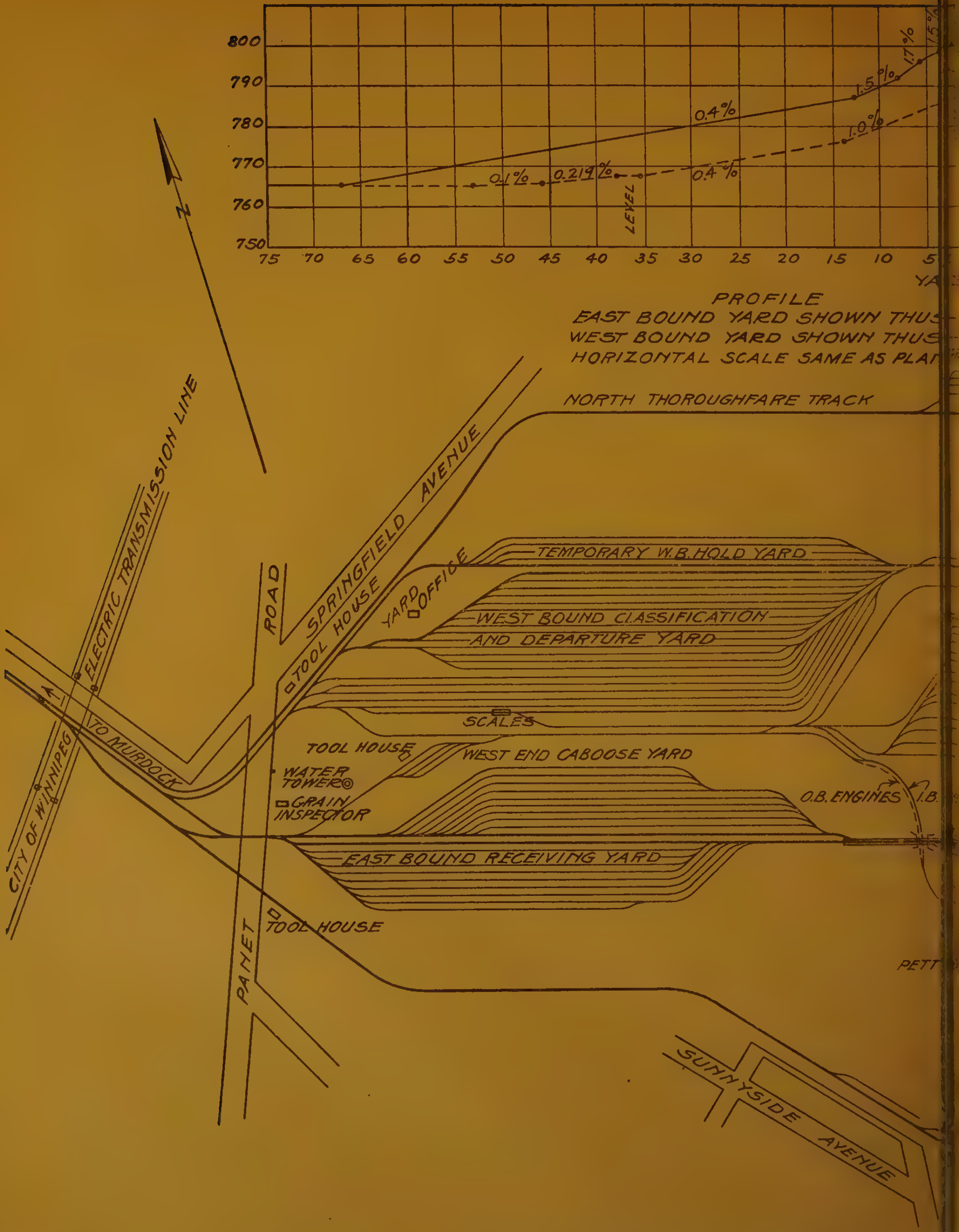
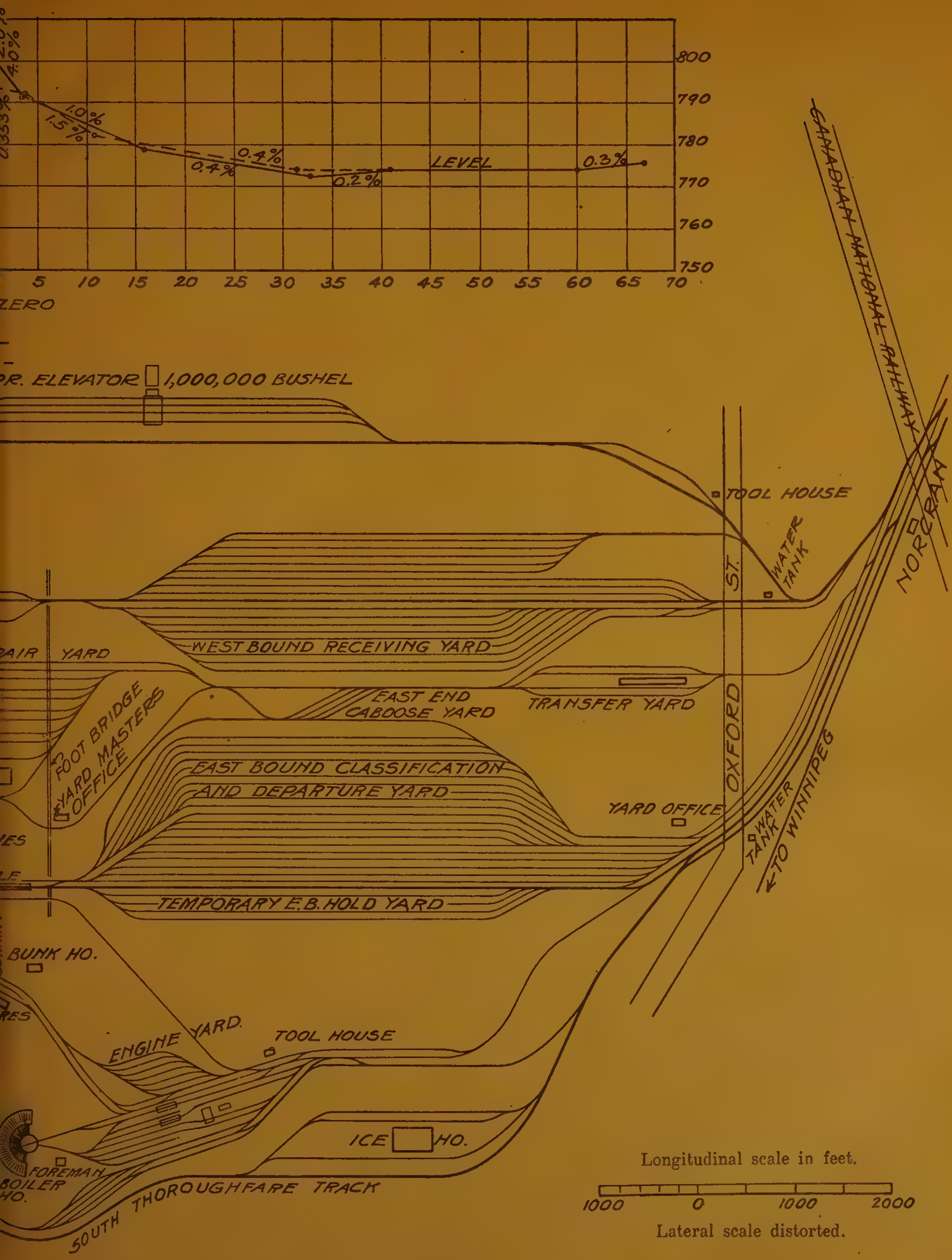
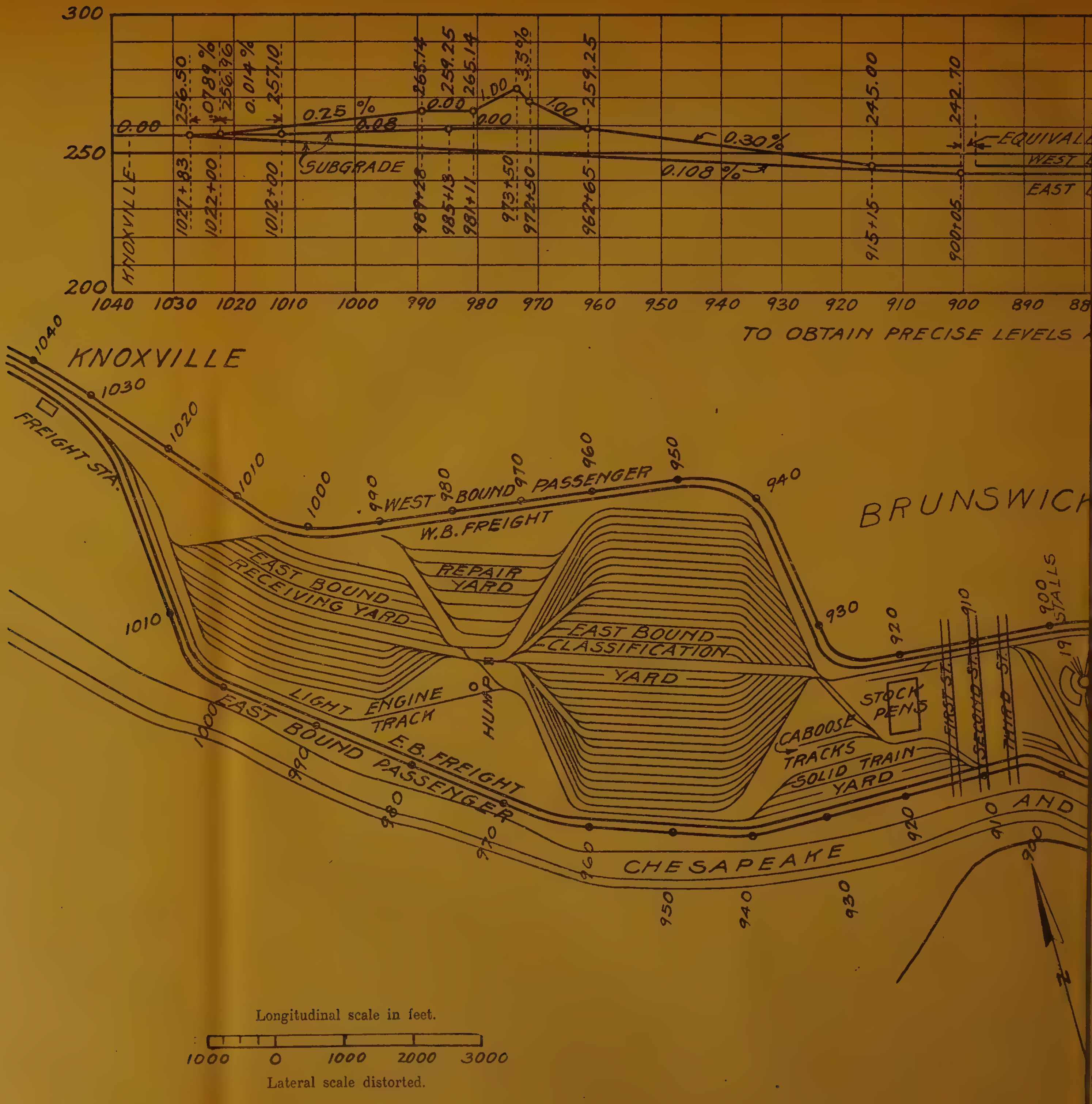


Fig. 6. — Canadian Pacific Railway Company. —



of North Transcona yard, Winnipeg, Canada.



Longitudinal scale in feet.

Lateral scale distorted.

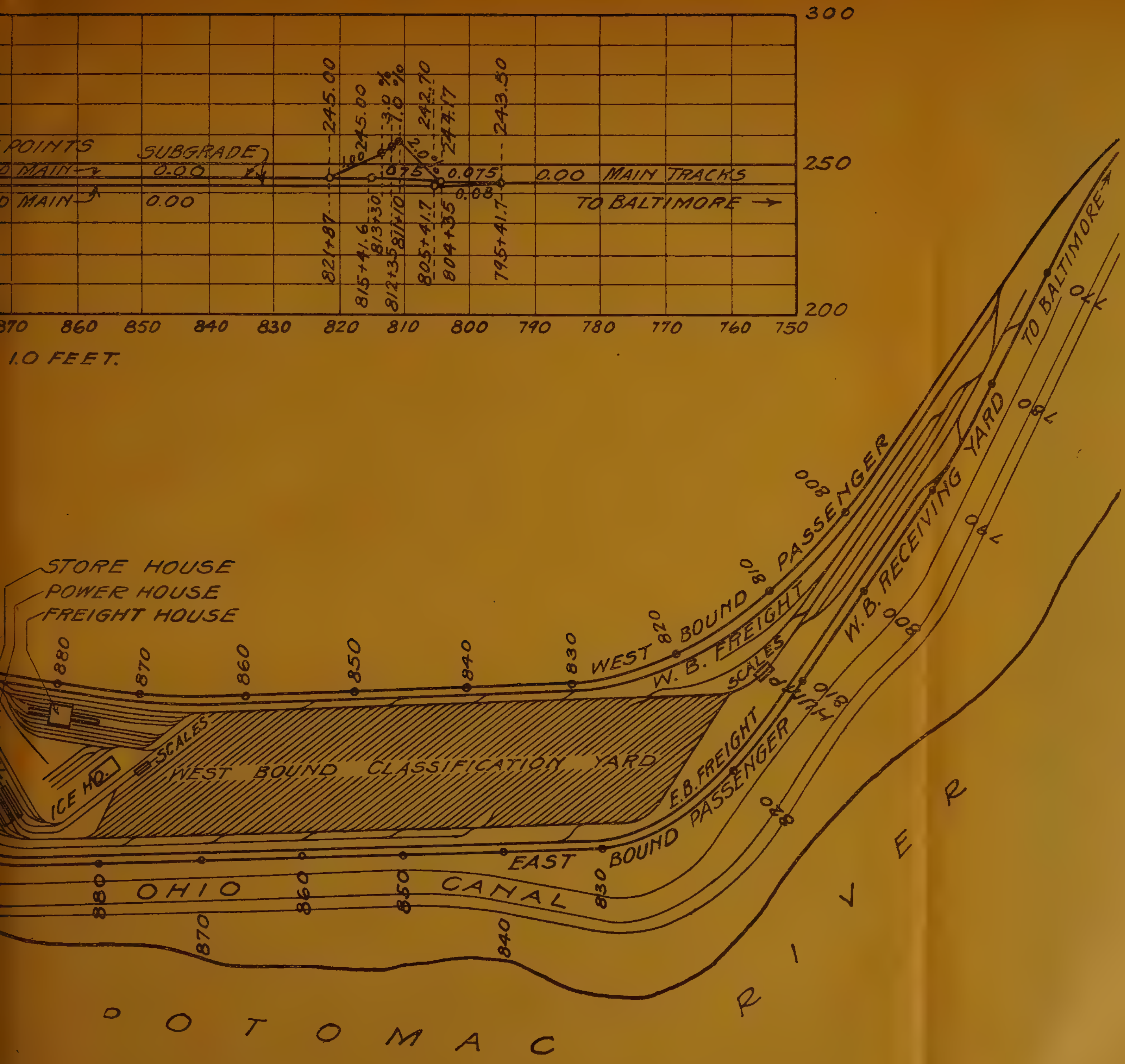
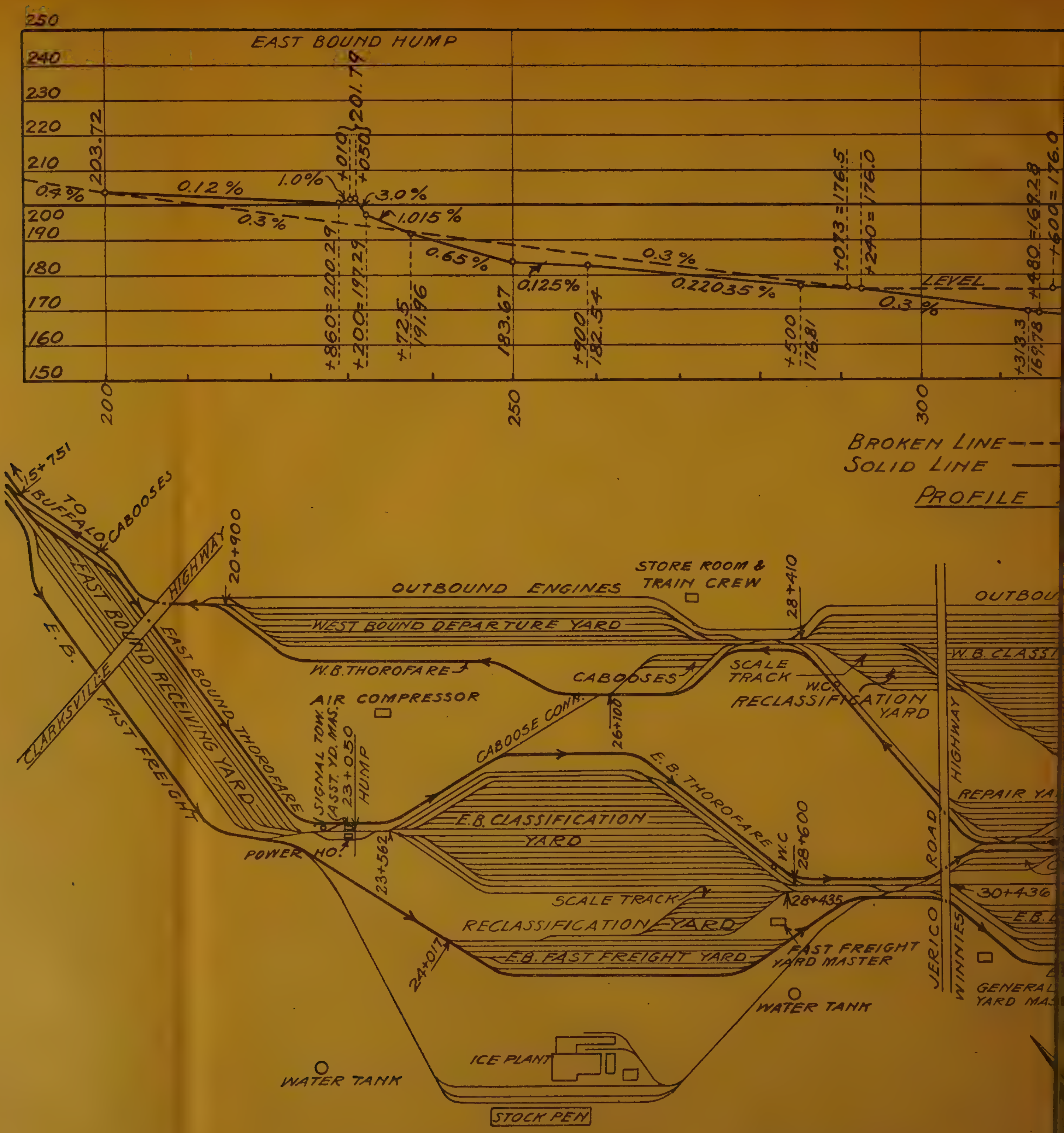


Fig 7. — Baltimore & Ohio Railroad Company. — Plan of Brunswick yard, Frederick Co., Maryland.



Longitudinal scale in feet.

1000 0 1000 2000

Lateral scale distorted.

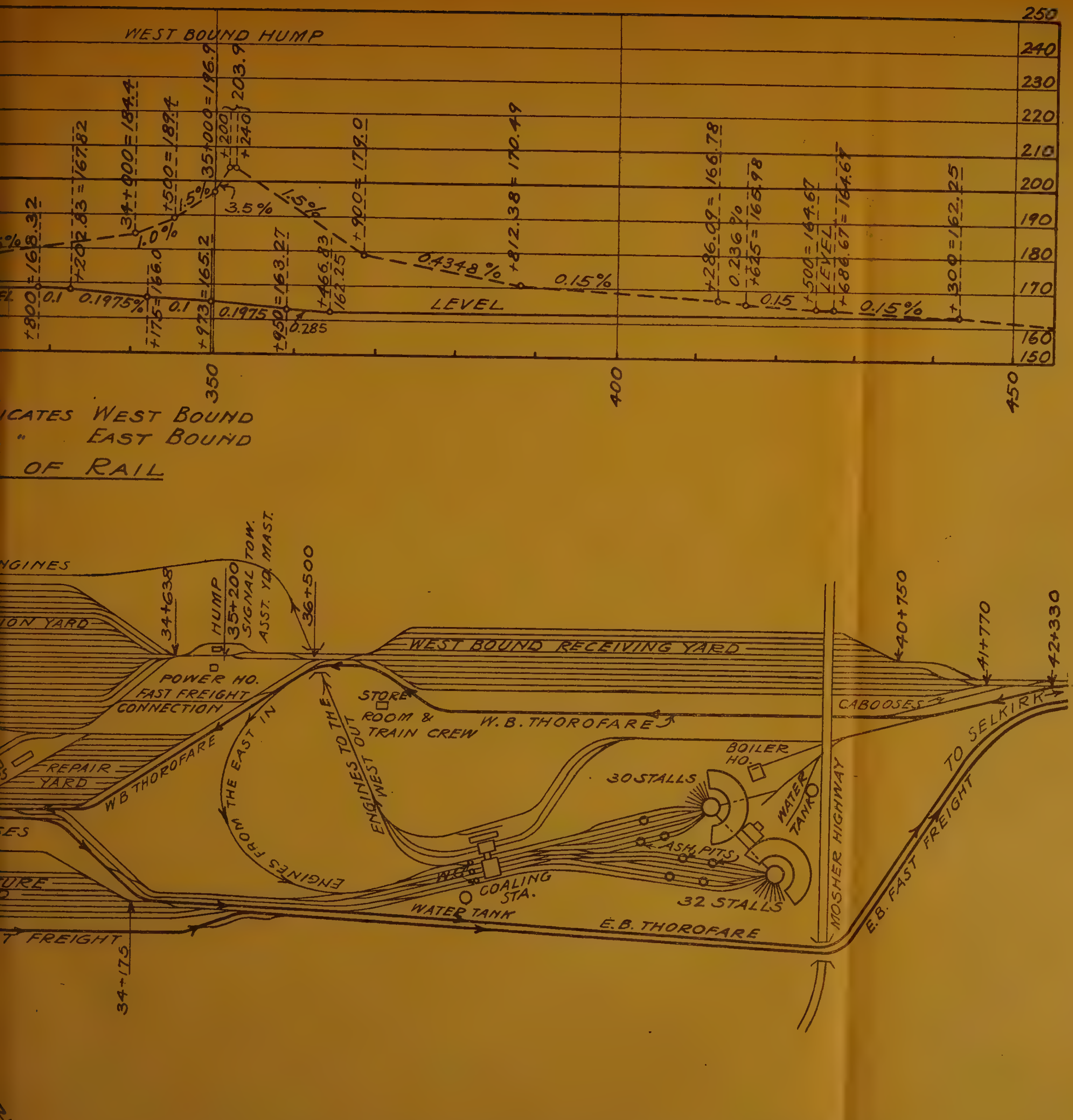


Fig. 8. — The New York Central Railroad Company. — Plan of Selkirk yard, Selkirk, N. Y.

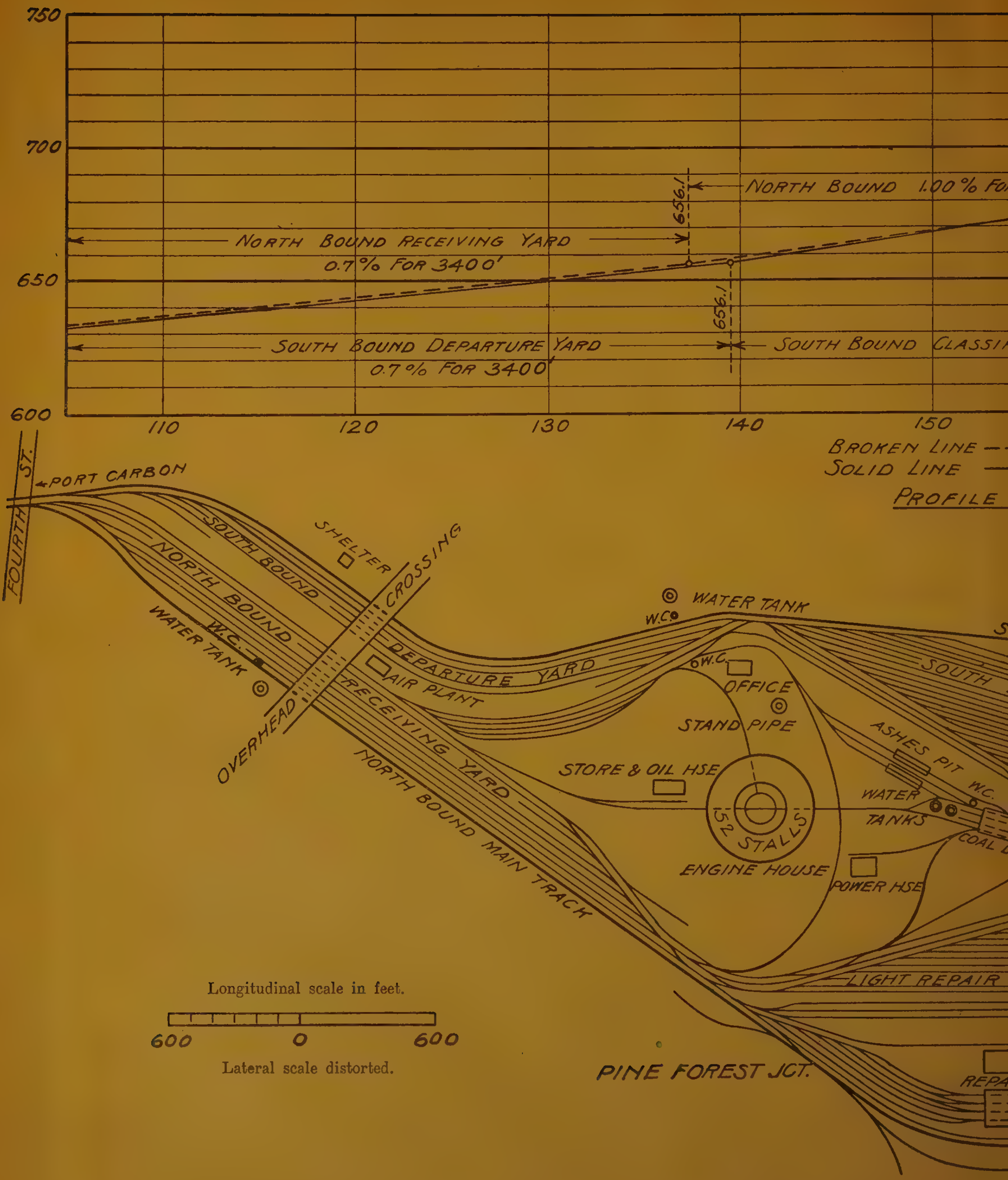
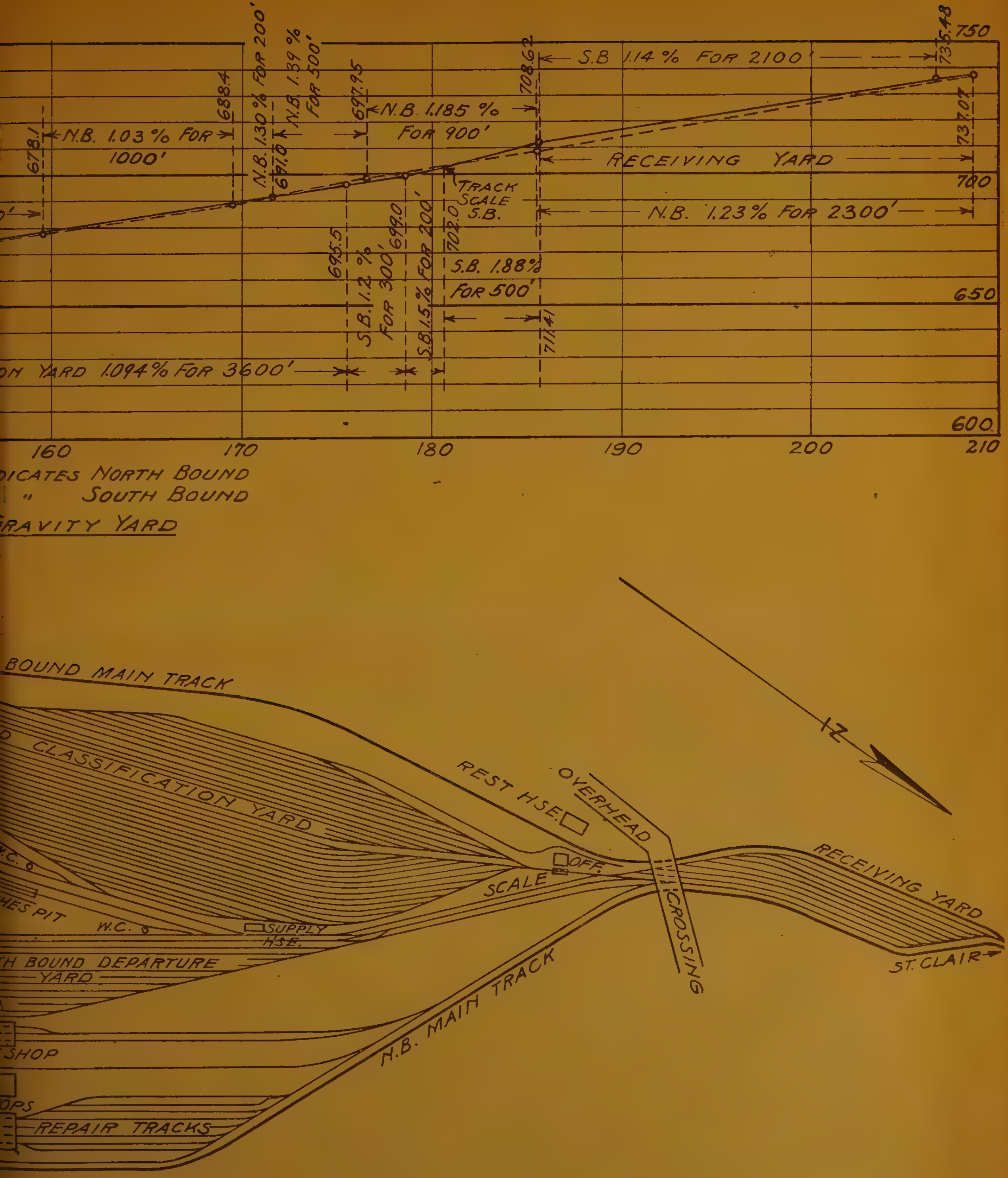


Fig. 9. — Reading Company. —



of St. Clair yard, St. Clair, Penna.

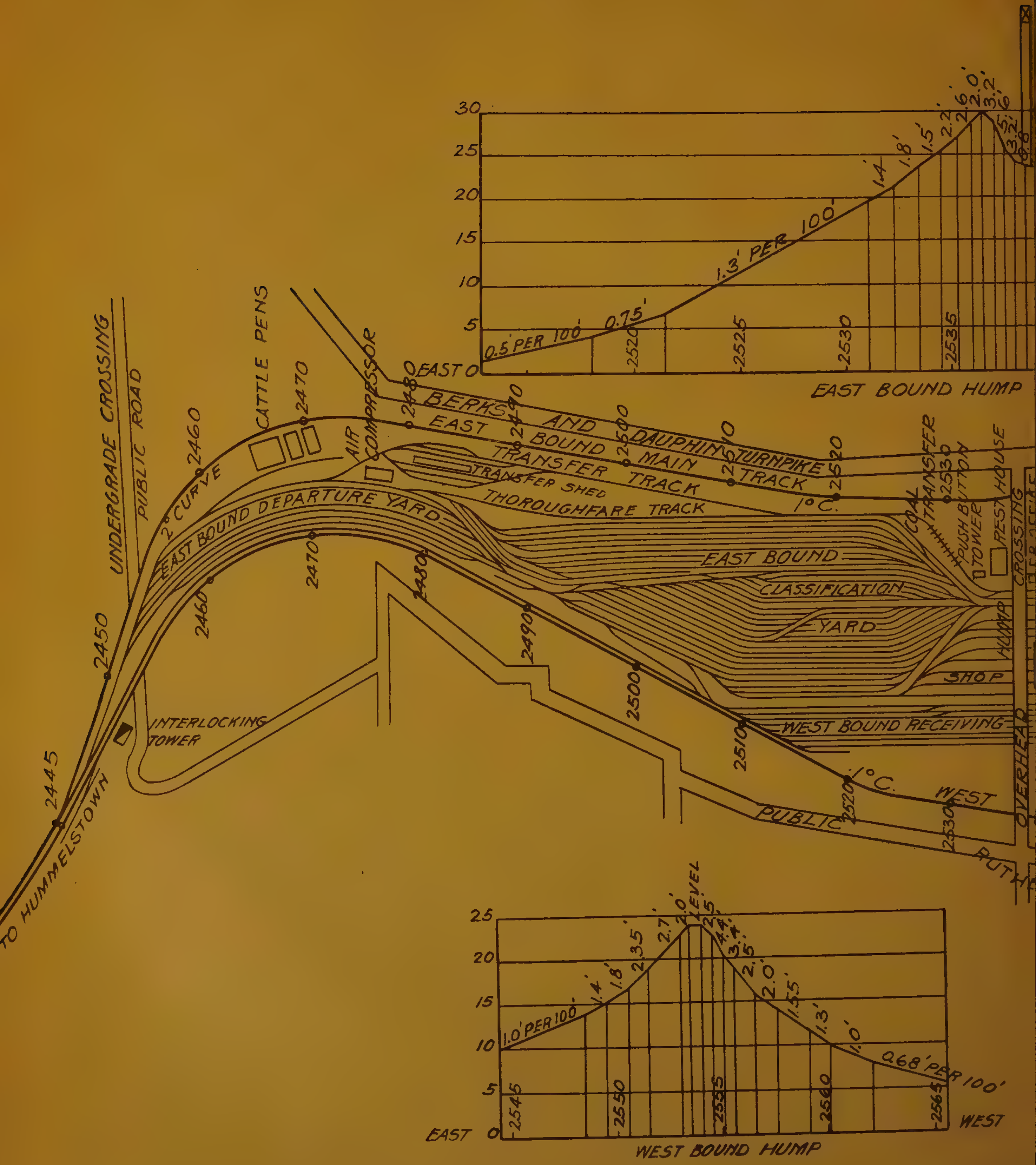
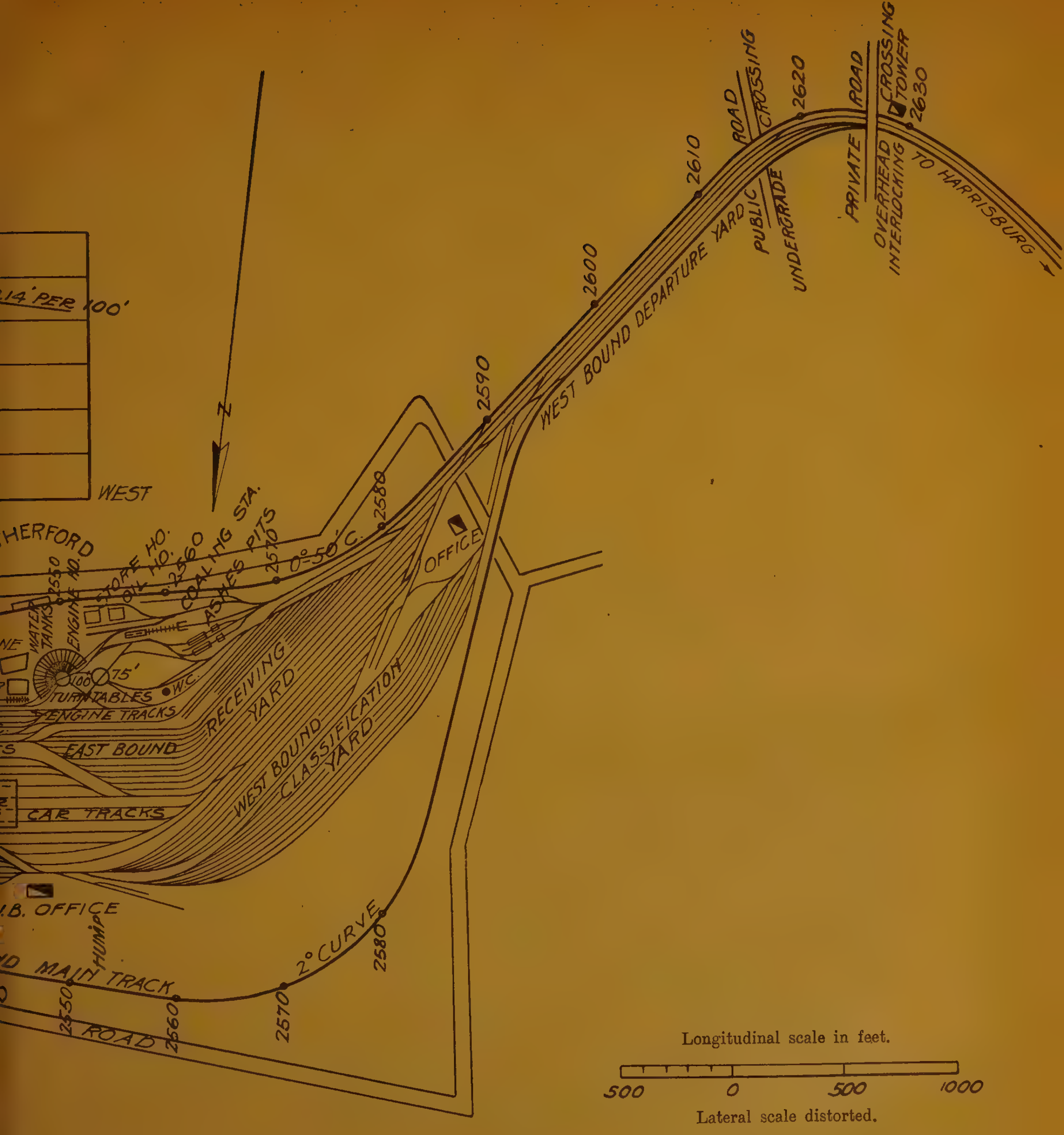


Fig. 10. — Reading Company. — Pla



utherford yards, Rutherford, Penna.

[625.61]

REPORT No. 1

(America, Great Britain and colonies)

ON THE QUESTION OF ESTABLISHMENT OF LIGHT RAILWAYS (SUBJECT XIII FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (¹)

By H. MARRIOTT,
LATE ASSISTANT TO GENERAL MANAGER, LONDON MIDLAND & SCOTTISH RAILWAY.

Figs. 1 to 14, pp. 857 to 869.

In thinking over the best way of dealing with the subject on which I have the honour to report, it seemed desirable to take stock of the present position in regard to light railways and, if possible, draw lessons from the experience gained since their inception.

With that object I issued a comprehensive questionnaire to those countries allotted to me, and should like to take the earliest opportunity of thanking the Officers of those Administrations who have taken so much trouble in preparing and sending answers to my enquiries.

The information thus obtained has been very valuable, but it is not considered necessary to incur the expense of printing the voluminous data which have been compiled.

In the British Isles, so far as it is possible to draw a line of demarcation between light and heavy railways, the mileage of light railways, so-called, can be taken to be, approximately, 1 500. This figure embraces lines of fourteen different gauges, the narrowest being 15 inches only (of which there are but 7 1/4 miles) and the widest, the standard of 4 ft. 8 1/2 in. (of which there are some 650 miles). Of the narrow gauges, the 3 feet gauge would appear to be the most favoured in the Kingdom, there being no less than 638 miles of track having this gauge alone.

Replies from the United States of America confirm the statement made before the Rome Congress by Mr. H. B. Spencer of the Southern Railway of that country, that the term « light railway » is seldom, if ever, applied there, the understanding being that light railways of Europe correspond with « dummy lines » and electric suburban trolley lines in that country.

In Canada there is nothing analogous to the light railway as generally understood, all lines (with the exception of about 250 miles on Prince Edward Island) being of standard 4 ft. 8 1/2 in., gauge. In recent years, however, there has been a recognition of the different classes of railways by the amount of cash subsidies that were given but no clear line marking this difference ob-

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(¹) This question runs as follows : « Methods of establishing light railways or lines for developing new countries. (Laying out, gradients, standard gauge, narrow gauge, etc) » tains. The lines are spoken of as main, main trunk and important or minor branch lines. The standards for main lines are not the same, varying according to the density of the traffic.

Dealing with Australia, the Government of New South Wales state that none of their lines can be regarded as light railways and the whole of them are constructed on the standard (4 ft. 8 1/2 in.) gauge. Up to the year 1890, or thereabout, it had been the practice to construct all railways, no matter what their location or what the probable business would be, in a thoroughly solid and substantial manner. In the year mentioned, however, the then Chairman of the Railway Administration suggested that a lighter system of construction might be adopted so as to minimise the capital cost of construction, and, in the first instance, the practice of constructing lines with the lightest possible earthworks, a rail of 60 lb. per yard instead of 71 1/2 lb. per yard previously used, and very lightly ballasted, was adopted.

This latter system, termed then the « pioneer » type of railway, has been with few exceptions adopted in connection with all construction since that time and a considerable portion of the total railways in New South Wales is of the light pioneer type, the permanent way being laid on earth formation and ballasted with earth.

From the Federated Malay States comes the information that there are no light railways, and Administrations in New Zealand state that the subject does not apply to them.

In India, according to published statistics, there are about 15 000 route miles of metre gauge and about 3 000 miles of 2 ft. 6 in. gauge railways, but whilst in Europe the metre gauge has been largely adopted for the purpose of light railways, metre gauge lines in India, or the greater proportion, are heavily built main lines, and, therefore, cannot be regarded as light railways. The place of light railways in India has, to a large extent, been taken by the so-called feeder lines of 2 ft. 6 in. gauge, the development of which has occurred in the course of the last twenty years. These lines are usually constructed in a substantial manner, and the rolling stock in use is surprisingly large. The permanent way is usually of 41 lb. per yard, flat-bottomed rails laid on wooden sleepers and ballasted with broken stone throughout.

The average cost per mile on a pre-war basis, including all equipment, was about Rs. 15 000, equal to £1 000 at the exchange rate of Rs. 15 to the pound.

There are also some 100 miles of 2 feet gauge railway in India but they have as a general rule been regarded as less efficient than the 2 ft. 6 in. gauge lines and it has been strongly urged that the latter gauge should be the standard for feeder lines in India.

It may be mentioned that feeder lines in India are considered as highly important, as the greater part of the country is insufficiently served by roads.

In India there are also light railways of the standard, or 5 ft. 6 in. gauge, and of the metre gauge, making physical junctions with the main line railways, thus avoiding transhipment, but the generally accepted view in India seems to be that for the development of the country, where the traffic to be expected is small, the greater cheapness of the 2 ft. 6 in. gauge more than balances the expense and inconvenience of transhipment if the length of the branch or feeder lines exceeds, say, 20 or 25 miles.

As regards Jamaica, a very interesting report was made by Lieutenant-Colonel

Hammond to the British Colonial Office in 1923, from which it appears that there are no light railways on the island, the gauge of the Government Railways being 4 ft. 8 1/2 in., and the total length, including branches, 200 miles.

A mileage of 200 to a total area of 4 450 square miles or 22 1/4 square miles per mile of track shows that Jamaica, so far as mileage is concerned, is well supplied with railways, but though the actual amount of railway is considerable the system is said to be seriously handicapped in several ways. It is considered that a 3 ft. 6 in. gauge, or metre gauge line, would have suited the mountainous nature of the island much better than the standard, as it would have been cheaper in capital cost and would have had ample capacity for the traffic.

As regards South Africa, at the 31 March 1923, there were 1 135 miles of narrow gauge railway in the Union, of which 437 miles were in South-West Africa.

* * *

The subject « light railways » has been under discussion in one form or another at previous meetings of this Congress and there appears to have been some doubt as to the real meaning of the term.

What is regarded as a « light » railway in one country may be the recognised standard line in another. Take, for example, the 3 ft. 6 in. gauge railways in South Africa, where heavier engines and wider rolling stock, with a better proportion of live load to tare weight are used than in the case of railways of 4 ft. 8 1/2 in. gauge in other parts of the world. Again, in India, where there are about 3 000 miles of 2 ft. 6 in. gauge (as well as some hundreds of miles of 2 feet gauge), the width of the carriages is 7 ft. 6 in. and the wagons carry a load of 16 tons.

(1) A departure from standard gauge is not an essential characteristic of « light » as distinct from « heavy » railways. A light railway may be of normal gauge or it may not, and the erroneous tendency to regard the terms « light » and « narrow gauge » as synonymous is no doubt due to the fact that in the nature of things the question of departing from the normal practice has arisen most frequently in connection with the promotion of light railways.

Mr. J. C. Mackay in his book *Light Railways* defines light railways as railways constructed to a lighter standard than the main lines of the country, worked at a slower speed, and with less accommodation for passengers and goods, but capable of carrying the main line rolling stock, but not the main line engines.

That well-known authority on transportation, Sir William Acworth, has stated in this connection that « a definition is in the nature of things impossible », but « a light railway must be something simpler and cheaper than an ordinary railway ».

Evidently something of this kind was contemplated when the Light Railways Act of 1896 was passed by the British Parliament and the Light Railway Commissioners then appointed (whose duties two years ago were transferred to the Ministry of Transport) were authorised to settle the terms of the draft Order submitted by the Promoters and insert any further provisions for the public safety which appeared to them after local inquiry to be necessary.

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(1) Report of Light Railways Investigation Committee, 1921, Ministry of Transport.

Notwithstanding the greater elasticity and simplicity of procedure afforded by the above-quoted Act and the later one of 1912, it cannot be said that there has been any appreciable development in Great Britain in opening out new districts by means of light railways, and only a few of the constructed lines have been worked at a small profit. It is only in rare cases that the Ordinary Shareholders have received a dividend on their holdings. Further, the outlook is not promising having regard to the increases in costs of materials and working expenses, particularly since the eight-hours day was made applicable to employees on light railways.

The following particulars culled from a recent Report of the Ministry of Transport are very interesting as showing the small development which has taken place in Great Britain under the operation of the Acts of 1896 and 1912 :

Number of applications..	738	Mileage...	5 217
Number granted..........	477	— ...	2 235

Of these however only 936 miles have been constructed, whilst a further 68 1/2 miles were under construction at the 31 December 1923.

The foregoing figures clearly indicate that there has been no lack of enthusiasm on the part of Promoters in bringing forward schemes for development by light railways but rather that there have been circumstances which have tended to prevent the ultimate attainment of the objects sought.

Further evidence of difficulties with which Promoters have been confronted is found in the fact that of the sum of one million sterling made available by Statute for advances by the British Treasury, only £226 000 had been advanced up to 31 December 1923, in respect of 144 miles (£165 305 by way of free grants and about £60 700 by way of loans) whilst a further amount of £200 475 had been conditionally promised in respect of 83 1/2 miles which had not been proceeded with. Thus, of the original Treasury Fund more than half was not assigned. Since the passing of the Railways Act of 1921, the British Government have agreed to subscribe £162 500 in respect of 44 miles of line under construction.

What is the reason for this disappointing state of things in Great Britain (after paying due regard to the world-disturbing factors of the last ten years) in contrast to the high degree of efficiency attained by the principal railways and also by the light railway systems in Belgium, etc.?

In the opinion of the Light Railway Commissioners one of the chief reasons why light Railways have not been constructed in rural districts was that the character of the cultivation was not such as to yield sufficient produce to afford a paying traffic or to support upon the land a population sufficient to provide a remunerative passenger and general traffic. The view is held that in Great Britain there are yet many and large rural areas which are capable of and should obtain a state of development in which light railways would form an important factor in any system of local transport organised on an economical basis.

Another reason to which this failure to carry out the construction of authorised light railways may be attributed is the difficulty in raising the necessary finance either by way of subscriptions from the public or local authorities or by inability to comply with the conditions under which advances are offered under the Light Railways Acts.

The Light Railways Commissioners

ascribed this in great measure to the fact that the Acts did not empower the Treasury to advance more than a proportion of the total capital required and that in recent years the requisite balance in the shape of private capital had been seldom forthcoming. Another and even more potent reason for the inability to take advantage of Treasury support was to be found in the fact that a contribution made in the form of a loan under section 4 of the Act of 1896 ranks before the share capital of the undertaking concerned. This has tended to place the holder of Ordinary Shares at a distinct disadvantage and it is the Ordinary Capital, not the Debentures of the undertaking, for which it is difficult to find subscribers. On the Continent, on the other hand, the contributions made by Public Authorities are frequently on an equal footing with the capital subscribed by ordinary private investors.

In March 1920, the British-Minister of Transport appointed a representative Committee (including Sir William Acworth, Sir John A. F. Aspinall and other well-known authorities on Engineering and Transport) « to examine and report upon the future policy and development of light railway operation and construction in the United Kingdom, due regard being given to the possibility of utilising roads for mechanical transport as an alternative ».

The result of their investigations is embodied in a Report issued by the Ministry of Transport dated the 26 July 1921. This Report, with its voluminous Appendices, contains a complete survey of the subject and is worthy of careful study. The concluding paragraph is so important that I have produced it in extenso :

> In concluding our Report we should add that one of the broad results of our enquiry has been to confirm our impression that a new and different conception of the character and functions of a light railway is both desirable and necessary We are convinced that existing notions with regard to the construction and operation of light railways generally are based upon experience originally gained in the construction and working of the great main lines and that main line traditions have governed and hampered the economic development of the small undertakings.
>
> Light railways, in our opinion, should be regarded from quite a different angle. We think that, instead of endeavouring to maintain standards of speed and service somewhat akin to those adopted by main line undertakings, it should be recognised by all concerned that light railways are in an essentially different category and must depend for their success upon emancipation from main line conceptions of construction and operation. We are satisfied that a lower standard of speed is a first essential and that, with the adoption of such a standard the necessity for elaborate methods of construction and working would largely disappear, with the result that the economic position of the light railway industry could be radically improved, and that without any serious sacrifice of efficiency.

The average cost of construction per mile of ordinary light railway in Britain is very little under that of standard gauge, as shown by the following figures extracted from the British Light Railways (Investigation) Committee's Report :

Capital cost per mile, easy country.

	£
Typical 4 ft. 8 1/2 in. gauge line built to carry heavy locomotive (Kent & East Sussex Line)	6 367
Light Railway, 2 ft. 3 in. gauge, light locomotive (Campbeltown & Machrihanish)	4 910

	£
Light Railway, considerable part of line laid on public road, gauge 3 feet (Clogher Valley).	3 333
Capital cost per mile, difficult country.	12 000

It is probably correct that the present day cost of construction and equipment of light railways is not less than twice that of pre-war times, and an average return of little over 2 % per annum on the capital expended is not sufficiently attractive to investors. Careful study of the whole of the circumstances has proved that the poor financial results obtained from light railway working in Great Britain are not due so much to any failure to exercise economy in the matter of working expenses as to the smallness of the earnings in relation to the capital of the undertakings concerned, *i. e.*, broadly speaking, the amount of traffic with which they have to deal is insufficient to produce a reasonable return upon the capital on which dividends are payable.

Enough has already been said to demonstrate that if capital is to be attracted and the necessary stimulus given to the opening of new districts by rail communication the cost of construction and working must be materially reduced in comparison to what has hitherto been regarded as the standard in Great Britain. The remarkable achievements in Belgium (« Société Nationale des chemins de fer Vicinaux »), for example, in this respect are well-known and have been reported to earlier meetings of the Congress and need not be dealt with again in detail. No better example is within my knowledge of the development there made possible for affording cheap rail communication of metre gauge (Vignoles rails : 41 lb.) at a cost of about 56 000 fr. per kilometre. Lines of this standard meet local requirements but some lines are constructed for short distances with mixed gauges of 1 m. and 1 m. 435 (4 ft. 8 1/2 in.) a third or a third and fourth rail being provided for the purpose of enabling main line vehicles hauled by narrow gauge engines to use the light railway for the purpose of gaining direct access to certain classes of works, quarries, etc.

The question of gauge came prominently under notice of the Belgian authorities at the close of the Great War when the relaying of destroyed lines had to be settled and after thoroughly examining the subject in all its bearings they decided to adhere to the principle of the narrow gauge.

The British Light Railways (Investigation) Committee of 1921 also discuss this point at great length in their Report and arrive at the conclusion that « where a proposed light railway is to be so located that no connection with the main line is possible or likely to be required, the choice of gauge may be determined in the main by considerations of economy in construction and maintenance ». They recommend, however, « that where connection is to be made with a main line or there is reason to think that such connection may ultimately be necessary, a narrow gauge should not as a rule be adopted unless the proposed light railway is to have a lead of more than 20 miles or is intended to form an integral part of an existing narrow gauge system which could not advantageously be converted to standard gauge, and that in cases where it is decided to depart from the standard the gauge selected should be 2 ft. 6 in., which should in future be regarded as the standard dimension for narrow gauge lines ».

In the development of new countries and districts where the traffic prospects are not sufficient to justify the capital cost of a standard gauge line, a 2 ft. 6 in. gauge might be laid cheaply in such a manner and on the understanding that it can be easily lifted if and when a standard gauge line is justified in the general interest.

It has been said that the cost of constructing a line of narrow gauge is very little less than that of one of normal or standard gauge and this may be true in countries where land is cheap and the country is « easy » from the engineering viewpoint but where land and labour are costly every foot of width and every cubic yard of excavation and filling involved represents a highly important element in the consideration of expenditure.

It will probably be urged that such a narrow gauge system would carry with it great disadvantages in transhipment, but these can in many cases be overcome by organisation or by the use of mechanical appliances. A simple and effective method adopted at some junction stations in Belgium is to raise the narrow gauge lines so as to bring the floor of the wagon to the same level as that of the wagon on the main lines which enables transhipment of traffic to be made easily and at small cost.

The cost of transhipment as represented by the time occupied in the handling of goods may also be minimised by the use of « containers » transferable to main line wagons or by the adoption on the narrow gauge line of wagons the bodies of which can be transferred to the main line, but in such cases it has to be borne in mind that freight charges would be raised by the main line Companies in respect of the « container », whilst the use of them would entail the provision of cranes at small stations where such apparatus would not be otherwise necessary.

Another system devised to obviate the trouble and delay of transhipment is that which is in operation at Waterhouses on the Leek & Manifold Light Railway (Staffordshire) by which trucks of normal gauge can be transferred to and from the light railway. These trucks are run over the latter by means of transportation cars which are on bogie wheels and have rails corresponding with the normal gauge, upon which wagons, etc., of that gauge are placed; the top rails of the transportation car fitting to the rails on the permanent way of the ordinary gauge railway at the junction of the two lines.

Mr. J. C. Mackay states that « reduction of gauge enables curves of very small radii to be used, and whilst a 5 chain radius is as small as it is convenient to go on a 4 ft. 8 1/2 in. gauge, a 3 chain radius can be used on the metre gauge and a 1 1/4 chain radius on the 2 ft. 6 in. gauge and the railways will still be in good working condition ».

The question of curves in laying out a line in a difficult country is one of great importance as it enables a railway to follow the contour of the ground, to avoid heavy embankments, cuttings and tunnels, and by these means to effect a greater saving in first cost.

In the development of poor districts, light railways are of much more service than the main line. The main line being of considerable cost, must be taken as straight as the « lie » of the country will allow between the two objective points, and cannot, therefore, deviate to the right or left for the purpose of serving an outlying town or moderate-sized village, and the working of the traffic will not allow of frequent stoppages for passengers or goods at small stations. The local railway, however, for the purpose of securing traffic and following out the intentions for which it was constructed can go out of its direct route to serve a large farm or small village and the cost will not be greatly enhanced thereby. With local railways as feeders to the main lines an enterprising farmer, for instance, might extend the siding right into his homestead and by means of a portable railway convey the trucks to the very spot where he wishes the goods to be taken up.

Whatever disadvantages there may be by the departure from standard gauge are more than counter-balanced by the saving in construction cost resulting from the flexibility of alignment rendered possible by the use of short radius curves with consequent reduction in the cost of earthworks, ballasting, sleepering and special structures.

It is the general practice in Great Britain for light railways to be fenced throughout. Having regard to the conditions prevailing in the country, complete exemption from the obligation to fence could not reasonably be expected, but in undeveloped countries there would be many places where the requirements in this respect could be made more lenient without sacrificing either safety or convenience. Much depends on the speed of the trains and local conditions, but if the lines were classified according to a speed limit as suggested by the British Light Railways (Investigation) Committee of 1921, there should be little difficulty in giving Promoters some relief under this head.

In the construction of a light railway the permanent way is generally the most costly individual item and the weight of the rail to be chosen is, therefore, a factor of the first importance. This cannot be determined, however, without reference to the maximum axle load to be carried and to the speed which is to be observed.

In all Orders, etc., authorising lines constructed in Great Britain since the passing of the Act of 1896, specific regulations have been laid down regarding axle-load, weight of rail and speed. The speed standard generally adopted for the standard gauge light railways was a maximum at any time of 25 miles per hour, the weight of rail varying from 56 lb. per yard for a 12-ton axle-load to 70 lb. per yard for a 16-ton axle-load, but on narrow gauge lines with smaller axle-loads lighter rails were prescribed.

Investigations show that out of 24 light lines of normal gauge constructed up to 1908, 21 adopted a heavier rail than the minimum prescribed in the Order. In most of these cases the heavier rail selected was second-hand and probably more economical to purchase than new rails of the lighter weight prescribed, but in some cases where a lighter rail was first laid it was found to be inadequate for main line engines with axle-loads of prescribed weight, and also to be uneconomical from the point of view of maintenance. The relative standards were, therefore, increased in 1908, and in the result a rail of 58 lb. per yard was prescribed for an axle-load of 12 tons; 64 lb. per yard for a load of 14 tons and 70 lb. rail for an axle-load of 16 tons.

Mr. J. C. Mackay states that the « weight of rail should not exceed 30 lb. per lineal yard on which a four-coupled engine weighing 15 tons will haul a gross load of 150 tons up a gradient of 1 in 100 or 75 tons up 1 in 50. Engines up to 25 tons can be used on this rail with a haulage capacity of 225 tons up 1 in 100 ».

In the view of the Light Railways (Investigation) Committee the considerations which should guide the appropriate Government Department in deciding whether any particular line should or should not be treated as a light railway under Section 18 of the Act of 1896 are intimately associated with factors of speed, permanent way construction and weight of rolling stock.

They suggest that *maximum speeds* might be found to constitute one of the most important governing factors and that so far as this particular factor is concerned, light railways should be classified in two groups as follows :

1° Lines having an authorised maximum speed of 25 miles per hour, and

2° Lines having an authorised maximum speed of 15 miles per hour.

The extent of the technical advantages which may safely be conferred on light railways will necessarily be determined by the limitations of speed which these undertakings will be willing to accept, and a classification of the kind suggested would admit of the elasticity of treatment and ensure that undertakings desiring to obtain the fullest measure of advantage might do so by adopting speed limits specified for lines in class 2.

Another burden has been put upon railway companies since the war in the shape of heavier rates for road improvement and maintenance. The enormously increased use of the roads by mechanical transport has necessitated a higher standard of road construction and maintenance, and the railways have not only had to bear a greater proportion of the cost of these services but they have suffered substantial losses of revenue by reason of the diversion of traffic, mainly of the better paying classes, which has been attracted from the railways to the roads.

It is well-known that Railway Companies generally are feeling the effects of competition by road motor vehicles and this competition is particularly keen in the case of short distance traffic. Bearing in mind that few light railways have any considerable length of lead it is to be expected that the effects of this competition will be felt in no small degree by them.

In considering the policy which should govern the future construction of light railways, the post-war development of mechanical road transport cannot be disregarded. One cannot fail to recognise that road transport services are daily meeting a public need and there may be instances in which a motor service may ultimately prove more economical and efficient in the opening out of new countries, than a light railway service provided suitable roads are available.

In this connection it must be borne in mind that whilst the construction of new light railways would involve the purchase of land, the construction of permanent way, and provision of depots and stations, road transport does not call for such expenditure.

In an endeavour to ascertain how the cost of a road transport service would compare with that of a corresponding light railway service, the Light Railways (Investigation) Committee had estimates prepared on the assumption that the former would be required to bear a fair proportion of the cost of constructing (or of re-constructing) and maintaining the roads on which it would operate, but they found that no estimate which was based on a consideration of average costs or of the figures relating to a limited number of individual cases could be relied on to furnish any guide to general policy.

The question of whether the principle of « grouping » could be applied to light railways has been considered by those having practical experience of the working of such undertakings. Such a system would undoubtedly lead to economy in the centralisation of management, the purchase and supply of materials and stores by the establishment of central repairing shops. It would seem desirable that any development of new countries by light railways should as far as possible be dealt with from this point of view.

As illustrating the development which can be achieved in countries where there is almost an entire absence of restrictions the report of what has been done by the Buenos Ayres and Great Southern Railway Company in the Argentine during the last four years is very interesting.

By means of Decauville feeder lines the Company have aimed to extend the area under cultivation in agricultural districts by affording facilities for the removal of produce from farm to station at rates which would be unattainable if transport had to be done by carts.

Since 1907 the Railway Companies of the Argentine Republic have worked under the provisions of the Mitre Law which prescribes that 3 % of their net receipts shall be turned over to the authorities to be devoted to the construction and maintenance of the highways of the Republic under the jurisdiction of the National Roads Commission. Whilst the work executed by this body has no doubt improved the conditions it is generally conceded that the degree of maintenance actually practised is insufficient to cope with the deficiencies, and that the practice of surfacing these roads with earth, while giving temporary relief during dry weather, leaves no lasting results. The latter can be obtained only by the liberal use of durable stone which, except in certain confined areas, is a material exceedingly scarce in the Argentine Republic.

Although the introduction of the automobile has contributed to increased facility of movement, transport over the earthen lines of communication is conducted now, as it always has been, by means of horse-drawn vehicles with the handicap of slowness and uncertainty at the best of times, and during periods of continued wet weather transportation has perforce to cease altogether. Therefore, not only are the producers at the mercy of the cartmen, but to the first cost of production of the fruits of the land there has to be added a heavy item in respect of actual road transport, with the attendant disability of a highly variable factor in the matter of the period of delivery to railway stations.

A continuance of wet weather often involves the loss or abandonment of large quantities of valuable produce, a loss both to the farmers and to the Railway Companies, and under these depressing conditions the stimulus to add to the area under cultivation — especially in districts remote from broad gauge lines — is not present, and it may even be said that the impassable state of the roads is a direct deterrent to the spread of agriculture and population.

These were the circumstances, therefore, which actuated the Buenos Ayres Great Southern Railway Company in laying down the lines to which I have referred and of which they have supplied the following general description and illustrations. (Figs. 1, 2 and 3.)

The system of construction is simple, there is comparative freedom of action as regards working, and there are no costly requirements to conform to. The lines laid are of the Decauville 2 feet gauge type and they serve the purpose of feeding the broad gauge stations in

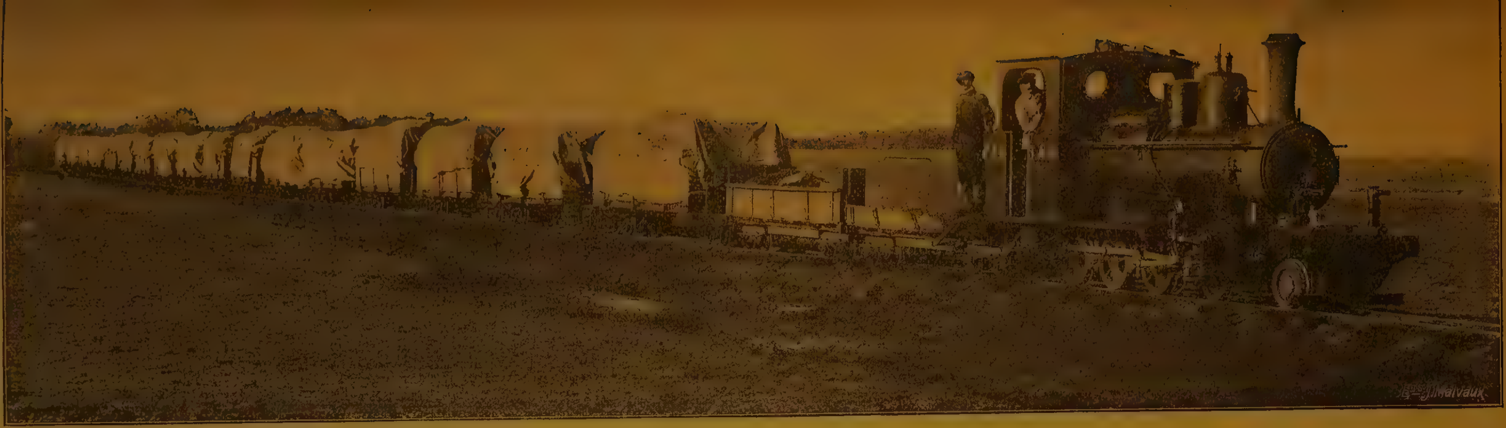

Fig. 1 — Decauville lines, Balcarce. Type of potato train, drawn by a « Hunslet » engine.

Trailing water tender and extra coal tender on ball bearing waggons. Other waggons 6 ton brass bearing waggons.

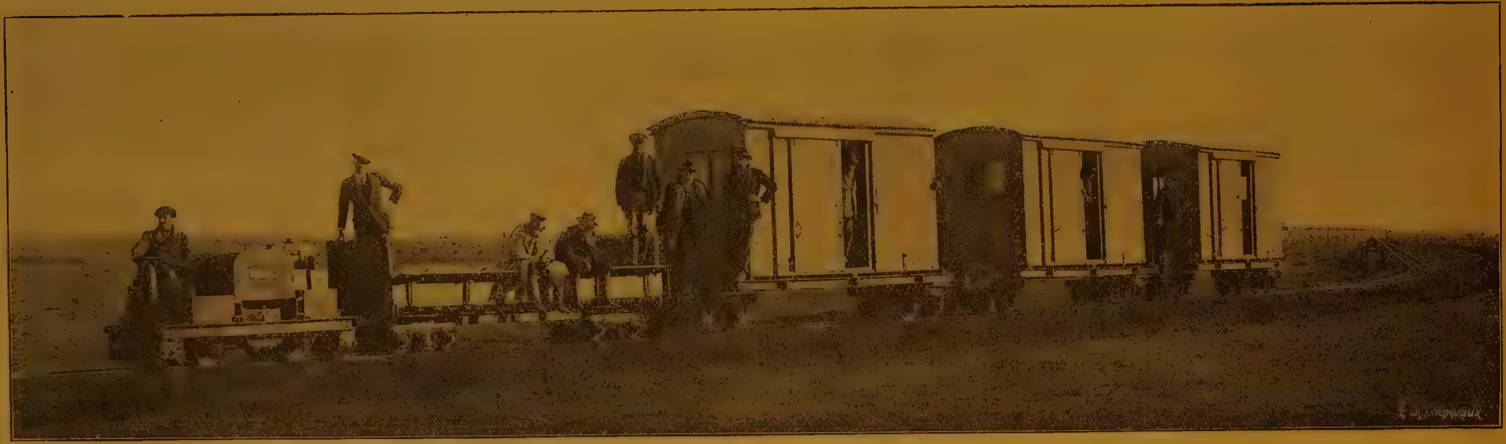

Fig. 2. — Decauville lines, Balcarce. Type of passenger and encomienda train, drawn by a 20 H.P. tractor.

Taken at kilometre 29 (Puerto de Diablo Line) 19 August 1922.

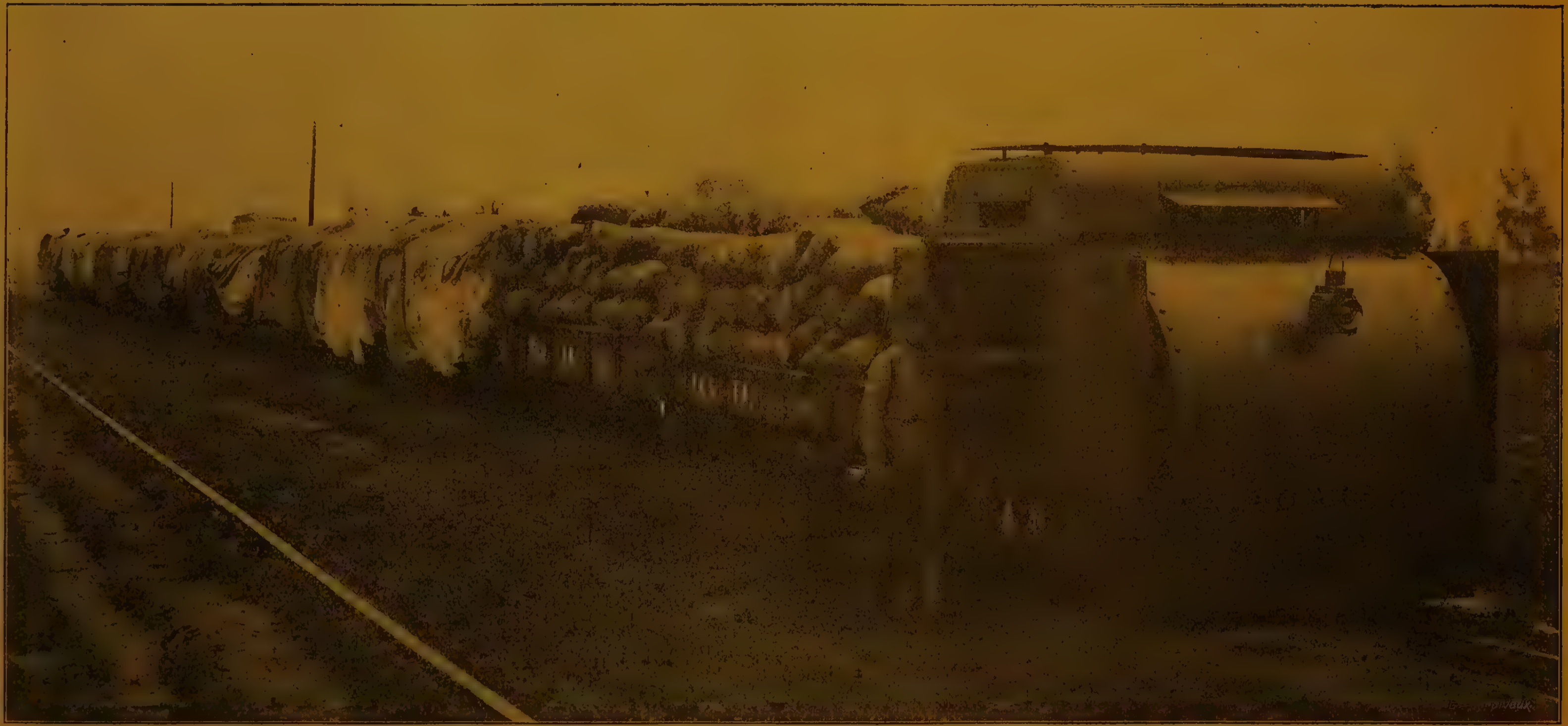

Fig. 3. — Decauville lines, Balcarce. Potato train, drawn by a 40 H. P. tractor.

Waggons, all of the ball bearing bogie type.

certain districts in order to afford rapid, regular and reasonable economic communication with the cultivated zones, and they have been designed to overcome the difficulties and cost of transport over the earthen roads of communication.

The lines are located and graded, in so far as it is possible with the maximum gradients, to give a surface line and to follow along the fences to avoid the intersection of properties.

All lines are single with crossing sidings every 5 km. Steam engines and petrol tractors are employed and the outward gradient (maximum) is 1 in 80 while the inward gradient (maximum) is 1 in 150. Curves are limited to 100 m. radius, although the sharpest permissible curve is 50 m. radius.

The rails vary from 20 lb. to the yard to 74 lb. to the yard and are fixed to steel and hardwood sleepers by bolts and clips or dogspikes.

The maximum axle-load employed is 3 1/2 tons and although there is no maximum prescribed, a load of 3 1/2 tons is considered to be the highest permissible load for 20 lb. track. For the heavier tracks the load could easily be increased to 6 tons per axle but it is not considered advisable to do so owing to the larger maintenance required to keep up the line.

The maximum speed over the line is governed by the capabilities of the tractor which is about 14 km. an hour. Steam locomotives are only used on the heavier tracks and these are limited to 18 km. an hour, which is considered to be the maximum speed compatible with safety.

Authority for the laying down of the lines is apparently extremely simple, consisting in the presentation of a plan and section and brief description of the line to the Municipality of the Department through which the line runs. Their sanction is all that is necessary, the Government or Railway Board having no power to intervene where the gauge of lines to be laid is less than 3 feet.

Although it is not necessary to purchase land for the purpose, permission is obtained in writing from each individual landowner for the line to be constructed through his property but this is purely an arrangement between the owner and the Railway Company, the Municipality having no right of intervention.

The whole system would seem to be constructed on the most economical principle. There are no restrictions as to level crossings and consequently crossings are not protected in any way and fencing is only put up where the line happens to run along a road owing to the objection of a landowner to its passing through his property.

There are no stations in the true sense of the word. At certain centres where traffic loading is intense a hut is placed for the accomodation of a telephone man who is stationed there to receive orders for empty wagons and give details of the loaded wagons. Crossing sidings at every 5 km. are used and loading sidings as well. At other points where the intensity of cultivation warrants it, dead-end sidings are laid down.

All rolling stock is owned by the Buenos Ayres Great Southern Railway Company, the wagons consisting of open and box ball-bearing bogie wagons with capacities varying from 3 1/2 to 8 1/2 tons, the tractive units being 20 and 40 H. P. « Simplex » tractors, 40 H. P. Baldwin tractors and « Hunslet » — 4-6-0 — locomotives.

The working, construction and maintenance of the lines is under the control of the Ways and Works Department of the broad gauge line, all matters of general policy coming under the jurisdiction of the General Manager.

The fares, rates and charges have no relation to those on the main railway line. The guiding factor was the establishment of a goods rate which, having regard to the more regular and more speedy service afforded, would be advantageous to the agriculturalist hitherto dependent on road cartage, and at the same time remunerative to the Company. Through rates are not in force.

Although there was a small loss in working the lines in 1922, the Buenos Ayres Great Southern Company attribute this to the fact that the line was only in its early stages of development and had not reached maturity.

It is estimated at present day prices of materials that the cost of construction per mile of Decauville lines in the Argentine is £1 240; £ 640 materials and £600 labour.

Great hopes are centred on the success of this new branch of the service, not so much from the standpoint of a business venture, per se, as from the opening up of a new agricultural country, with concomitant increase of traffic to the main line.

The advantages of Decauville transport over the present cartage system may be summarised as follows :

1° Traffic can be transported on the Decauville lines during wet Seasons, *i. e.*, when after heavy rains roads are impassable for carts;

2° When cartage is the only alternative, the farmer has to provide cartmen with food and fodder for their horses, in addition to reserving from 25 to 75 acres for grazing the animals; while the relations between farmers and cartmen are not always as amicable as they might be, owing to disputes occasionally arising about prices, etc. All these difficulties are eliminated by Decauville transport;

3° Cartmen continually alter tariffs, taking advantage of prevailing conditions, such as a big harvest or bad roads, when the cost of transport arises. In dry weather or with poor harvests when carts are plentiful cartmen lower rates and compete among themselves;

4° Carriage for a distance of 30 km. occupies on the round trip from 2 to 3 days whereas by Decauville line a few hours are sufficient. The average cart carried 8 1/2 tons so that to convey 100 tons 30 km., 6 carts with 90 horses would be required, each cart making 2 trips every 5 or 6 days in good weather; 2 trains, formed of 3-ton trucks, would do the same work in a day. With bogie trucks, one train would be more than enough;

5° The outstanding feature of this Decauville service once it has been firmly established, is that transport facilities from farm to station, in good or bad weather, added to the regularity of cost in moving the produce to the station, will greatly reduce the figure this service costs at present, and, therefore, diminish the cost of production to the farmer. This will enable the farmers to get more for their work, even at reduced prices for produce, than under ruling conditions, which subject them to all sorts of exactions and uncertainties on the part of the cartmen. Cheap production gives the farmer and the country generally an advantage in competing in the world's markets which does not need emphasising.

The adoption of the 60 cm. gauge was influenced by the fact that it has been demonstrated all over the world, more particularly in France during the war, that this type of line is capable of carrying very heavy traffic in a successful and economical manner, while it is not too heavy to provide a certain amount of elasticity in the event of it being necessary to remove the track from one locality to another, and lift and relay it in some more productive zone.

In constructing these lines, the Company not only had to bear in mind their value as feeders to the main line, besides giving better access to the stations, but also the impulse they would give to the development of hitherto uncultivated areas and in actual practice the latter effect has been abundantly produced. It was at first thought that these lines might profitably be laid along the public roads but reflection showed that in such a position they would be liable to serious damage by the heavy campcarts, sometimes drawn by as many as twenty-five horses, passing along these highways, whilst stray cattle would also inflict damage to the light earthworks employed in the work of construction. It was, therefore, decided that they should be laid through the camps, which has been done in practically every instance.

Although the conditions governing the construction of these lines in the Argentine are not common to all countries, it may be stated that it has been found that to be an economical and financial success, they must be projected beyond a 25 km. radius to the broad gauge station; anything inside this area being subject to keen competition.

The selection of operating centres was governed by the presence of cultivation in a stabilised form, complemented by the possibility of further large areas being placed under the plough, as a result of the arrival of the Decauville lines.

As was to be expected, the installation of this system of transport aroused considerable opposition from the local carters, who had hitherto enjoyed a complete monopoly of the transport operations in the districts concerned but this has now disappeared, the men having realised that it was hopeless for them to try to compete on equal terms, and they are now seeking to develop business at points beyond the field of influence covered by the Decauville tracks. This will naturally benefit the country as camps hitherto unprovided for and without adequate means of communication, will now have a surplus of carters to meet the want, at probably very much lower rates than in the past.

* * *

The deductions which may be drawn from a comprehensive study of the whole of the facts revealed during the preparation of this Report are, that any system of transport in the development of new countries should be fitted to the conditions which actually prevail, and that it should not be hampered by the adoption of standards of construction, equipment and operation better fitted to a more advanced stage of development. There are three factors involved: the traffic, the track and the machinery of operation, and these should be in harmony.

Discussion is frequently confined to construction alone, but it is the interaction of these phases of the problem on each other and on the traffic, which determines the economic success or failure of the installation. Hence the importance of a careful study of the problem in all its bearings.

The opening out of new districts depends very largely upon widely extended, cheap and efficient transport facilities. Any system of transport which can show substantially reduced first cost, upkeep and operating charges will confer a great boon. There must be pioneer tracks of some sort, whether road or rail, in undeveloped areas before a population can settle and develop, but the provision of these tracks is frequently held up owing to the high cost of construction, equipment and operation — a feature specially marked since the war. Again, if this primary difficulty be overcome and the capital be raised, the interest and standing charges are serious matters and exercise such a discouraging influence that it may take many years to settle a virgin country with a population of sufficient density to ensure enough traffic to make roads and railways of the usual type pay their way. The producer wants to be brought into close touch with markets, and to this end the transport system should be flexible and intimate. It should, in fact, go where the traffic is, eliminating subsidiary haulage as far as possible and giving a frequent and regular service at low cost.

To what extent can the need be met by established methods? (¹) Animal haulage subsists, but must obviously more and more give place, in general, to mechanical haulage in some form. Where roads exist, recourse may be had to the motor lorry. But traffic so carried demands specially good roads, and these, if they exist at all, cannot be as ubiquitous as is necessary. Further, the load which can be carried by one lorry is small in relation to the dead or non-paying load, resulting in high ton-mile haulage costs. Also, which is very important, the high tractive resistance absorbs power in a very serious way. Heavy motor traffic too is hard on the roads, so that maintenance charges are high. In fact, metalled roads suitable for the high axle loads of motor traffic are so expensive that the desired network of transport lines cannot, it would seem, take this form. Motor transport has its place as a collecting and distributing agency in large centres of population, where high class streets and roads are necessarily provided in any case but is not generally suited to an earlier and more elementary stage of development.

In the absence of roads suitable for mechanical transport the mind turns to light railways. Much has been expected from them, but as we have seen they are not being built to an extent commensurate with the need.

Experience has proved that, except in a few cases, track construction and equipment of light railways of the usual type cost more than the traffic can bear, and construction and equipment are inter-related. The tractive force of a locomotive being limited by the adhesion, the lower the adhesion value between the wheel and the track the greater must be the adhesion weight. For light railways with steel wheels on steel rails the adhesion weight should be about 4 1/2 times the maximum tractive force, and as rails, sleepers and roadbed must be proportioned to the axle-load of the locomotive it is plain that the construction cost of light railway track of the usual type is very seriously affected by the fact that the locomotive runs on, and takes its adhesion from, the rails. From these considerations it is seen that the cost of the track is some function of the tractive force developed per each driving axle of the locomotive or tractor employed. The insistent public demand for speed and power on main lines has resulted in a road-bed and equipment of a very high but very expensive order, which have been applied, in thought and in practice, to subsidiary lines to which

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(¹) Mr. Alexander Galbraith, F. R. S. E.: Article on « Roadrail » system (*Modern Transport*, 12 April 1924).

they have no completely relevant application. Topographical features, moreover, impose their will either by causing the location to be changed to suit the desired alignment in which case the traffic suffers, or by demanding heavy filling and cutting, which adds greatly to the cost.

On almost any railway, and certainly on light railways, the axle-loads of the rolling stock (other than locomotives) are, or may be, such that a lighter track would suffice if the rails had only to meet the needs of the rolling stock, just as light track suffices for animal haulage. By combining the principles of road transport and rail transport, taking the adhesion from the ground (where adhesion is high) and hauling the load on the rails (where resistance is low) a system has been devised called the « Roadrail », by which it is claimed to afford a light, cheap and efficient construction and equipment, adapted to the needs of a growing traffic.

In the « Roadrail » system (see figs. 4, 5, 6 and 7) the driving wheels of the tractor or locomotive do not run on the rails, but on the road-like surface of wheelways, either between or outside the rails (usually outside). The wheelways may be formed of any suitable material readily obtainable, e. g., stone, timber, concrete, or, it may be, under favourable circumstances, simply the natural surface of the ground. The driving wheels of the tractor are rubber-tyred, and have thus a high factor of adhesion on the wheelways, up to, 60 % of the adhesive weight, as against 20 to 22 % in the case of steel tyres on steel rails : a ratio of about 3 to 1. It follows that for a given tractive effort the load carried by the driving axle or axles of the Roadrail tractor need only be one-third, say, of the corresponding weight of the driving axles of the ordinary adhesion locomotive doing the same work; in other words the necessary tractive force can be developed with a very light axle-load, such as the wheelways can easily stand up to, while the rails carry no driving axle-load at all.

As an illustration, one might consider two small locomotives of the internal combustion type, of equal power, developing, say, 35 H. P. at the rims of the driving wheels at 3 miles per hour, corresponding to a tractive force of nearly 2 tons. No. 1 is a Roadrail tractor with rubber tyres and No. 2 an ordinary adhesion locomotive with steel tyres. No. 1 will require an adhesion weight of about 3 and one-third tons carried wholly on the wheelway; while No. 2 will require about 9 tons on the rail-supported drivers if it is to develop the full tractive force of 2 tons without slipping on the rails. For higher powers the adhesion weights will rise in proportion, and it seems clear the track must soon lose all title to be called « light » if the adhesion is to be derived from the rails.

It is claimed for the Roadrail system that by it a light railway can be really light in all its parts : track, tractors and rolling stock. The stock, preferably of the double bogie type, with a good ratio of paying to non-paying, or dead load, may have a low axle-load of the order of 2 tons, and thus the rails, sleepers and foundations of the track may be correspondingly light, with consequently low first cost and interest charges. Also, the high adhesion of rubber tyres on the wheelways enables comparatively light tractors to handle and control trains on very steep gradients, thus obviating the expense of filling and cutting already referred to.

The system may be a self-contained unit serving the varied internal needs of a large area, or may be applied as feeder lines to ordinary railways. Light branch feeders or tributaries can be thrown out to farms and factories, or a convertible type of light tractor may be used, which, when required, can leave the rail and collect traffic in out-lying districts and rejoin the rail at any point. An essential feature of the tractors is their ease of steering when on rail service. This is effected by means of the bogies which run on the rail and support the part of

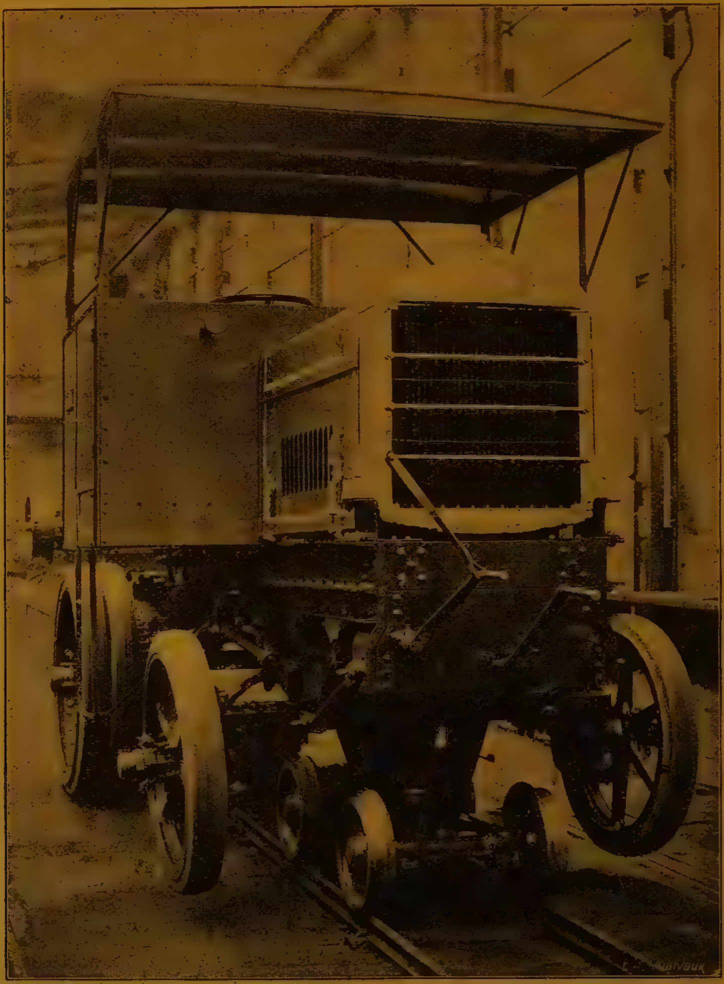
Fig. 4. — Road-rail tractor, petrol 50/75 H. P., single bogie type.

Front view, showing front road wheel.

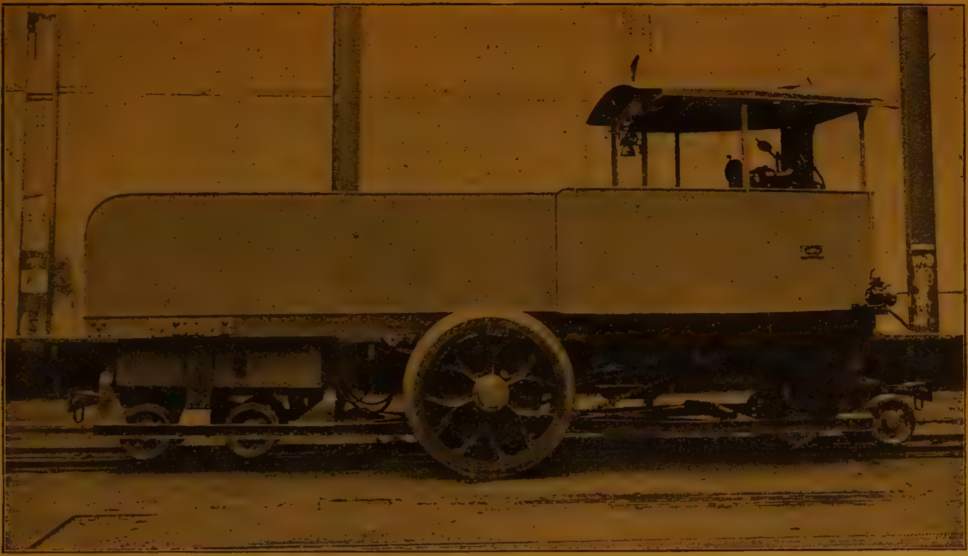

Fig. 5. — Road-rail tractor, steam double bogie type.
Side view, showing driving wheels lower than bogie wheels by the height of rails.

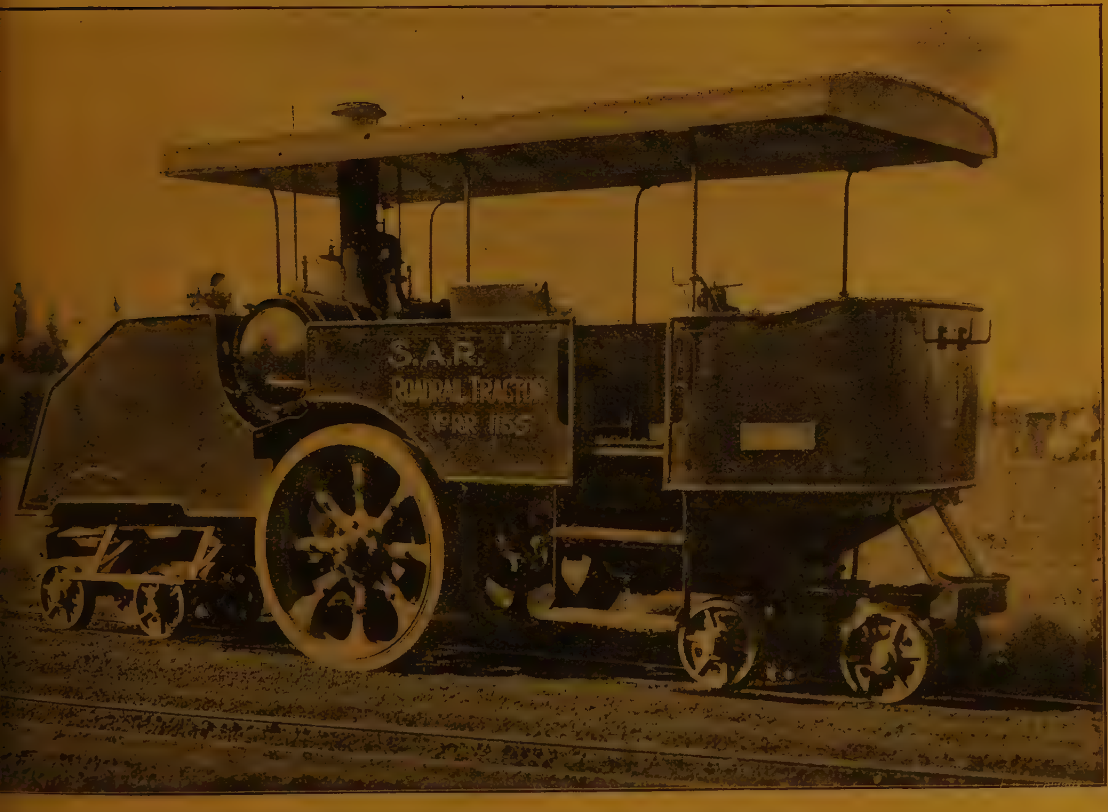

Fig. 6. — A Reversible steam road-rail tractor.
50 H. P., 2 feet gauge track, 16 lb. rails.

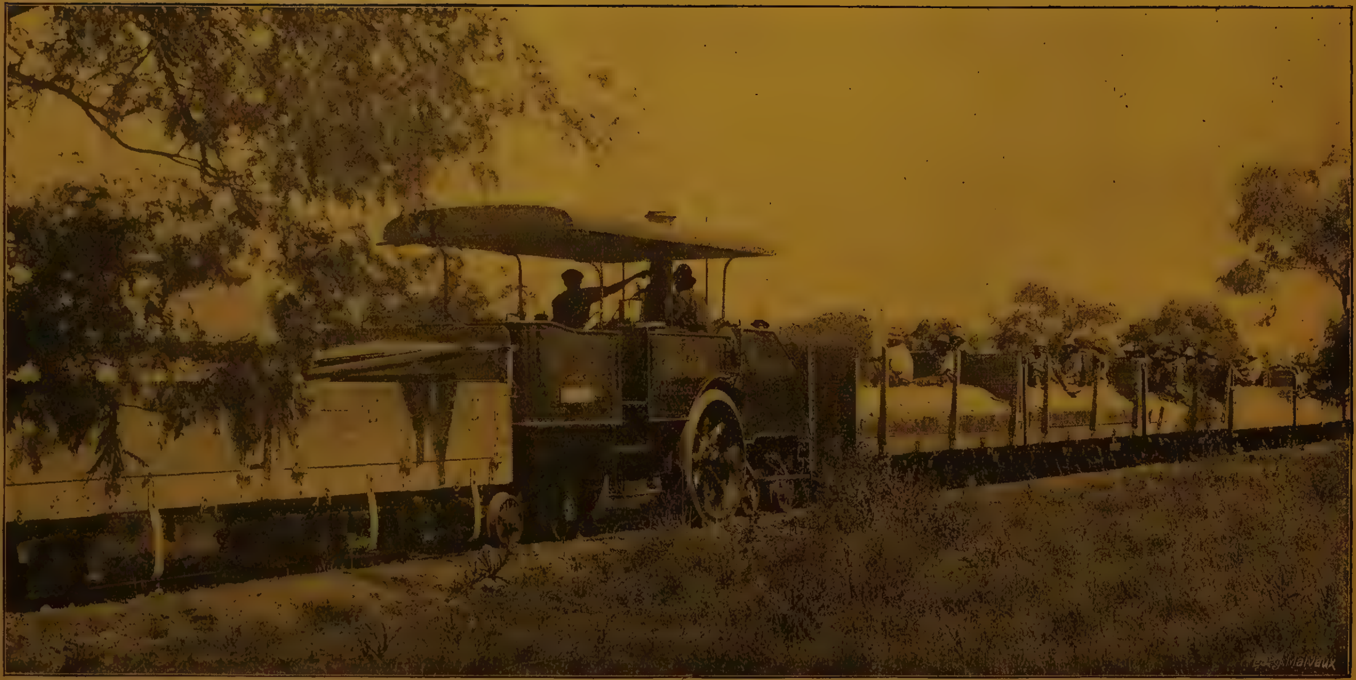

Fig. 7. — Reversible steam road-rail tractor and 110 ton train.

Note portion of train being propelled and portion being hauled.

the weight of the tractor which is not borne by the drivers, and prevent the driving wheels from straying from the wheelways. It is thus possible to work the road-railway by day or night, as any ordinary railway is worked, without risk of derailment, while the driver is left free to attend to the mechanism. Various designs of tractor are in use and under construction, and may be broadly classed under two heads according as they are convertible for either road or rail haulage, or of the « all-rail » type adapted for purely rail service.

Convertibility is of essential importance in many districts, as it enables the tractor to leave the rail and operate as a road vehicle where rail tracks have not been laid, thus increasing the radius of action of the system. The convertible or single bogie type tractor, when used for purely road service, functions as a motor hauler with or without trailers, but when working, as it normally does, on rail service, the front end of the vehicle is supported on a rail bogie, with the front road wheels clear of the ground. The greater part of the weight of the machine is on the rear drivers, which run on the wheel tracks and give the necessary adhesion as discussed above. The front end of the machine rests on its bogies through the medium of a ball or universal joint, which permits the driving wheels to accommodate themselves to any inequalities of the wheel track surface, without losing adhesion. The wheel tracks may be at or above the rail level, or as much as 12 inches below that level, without affecting the safe running of the tractor. The driving axle is normally differentially driven.

The machine shown in the first illustration (plate No. 4) has been specially designed and constructed for convertible service. The rail bogie is carried with the tractor so as to be always available, and conversion from rail to road, or vice versa, can be effected in less than a minute by the easily manipulated gear which is provided.

For certain services, however, a convertible machine is not required. The remaining photographs (figs. 5, 6 and 7) illustrate an all-rail machine of the double-bogie reversible type, which is extremely flexible and adaptable to large variations in both the road and rail surface. It is driven by a steam engine, but all tractors may be driven either by steam engines deriving power from coal or liquid-fuel fired boilers, or by internal combustion engines running on petrol or paraffin. The tractor for Uganda is built to the 24-inch gauge. The roadrail system in that country extends from Kampala to Bombo, a distance of 26 miles. It has a ruling gradient of 1 in. 25, except for two short lengths of 1 in. 20. The top surface soil has been removed throughout, and the wheeltracks gravelled, the rail track being unballasted. The capital cost of such a track is approximately £1 200 per mile. The illustrations indicate the flexibility of the tractor and the method in which it can overcome irregularities in the road, even if these irregularities constitute a series so close together that before the wheels are right over one they are on to another. It is stated that before leaving the shops, the all-rail tractor in question was put to a drawbar pull test, when the scale registered a pull of 5 600 lb. a surprising load considering the weight on the driving wheels.

The usual continental light railway gauge has been adopted for certain Roadrail installations, as also its practical equivalent 24 inches British. With rails weighing 16 lb. per yard, axle-loads of 1 1/2 to 2 tons are permissible. As already noted, the gradients in general may be very much steeper than is usual on light railways of ordinary construction operated by locomotives taking adhesion from the rail. Where desired, gradients of, say, 1 in 15, and curves of 30 feet radius may be included in the layout of the line, as compared with the usual limiting gradients of 1 in 40 and curves of 150 feet radius. Thus, the line can be conveniently located through producing areas, choosing the best route for development purpose, and reducing banking and cutting to a minimum.

It is considered that a Railroad track of equivalent capacity to an ordinary British light railway could be built for £1 250 per mile. Such a substantial advantage is bound to re-act favourably upon the economic position of any undertaking, and in conjunction with cheap and efficient operation, may turn a loss into a substantial profit. It may be useful at this stage to point out that in Great Britain to-day the cost of the metalled road 12 feet wide, to carry 400 tons per day, is over £5 000, that is, more than four times the cost of a mile of Roadrail track, and the annual maintenance cost about £230 per mile.

The Roadrail system has for some years been in actual operation in South Africa, Uganda and Morocco, and is stated to have given most satisfactory results. In Spanish Morocco a track 14 miles in length and of 60 cm. gauge was laid for military purposes. Over this track 450 tons of stores were hauled daily by three Roadrail tractors which replaced a fleet of 50 motor lorries and thus yielded a considerable saving of time and money. The track in question is now being extended another 25 miles. At Forgandenny, Perthshire, a Roadrail track, four miles in length, has been installed for the Stronachie Distillery Company. It is laid along the side of an old mountain road, one of the worst in Scotland, and with a 1 in. 12 grade. The tractor is of the convertible type. It is first used to haul heavy trailers through the village from the main railway station, and then mounts a narrow gauge track and completes its journey as a rail vehicle.

A demonstration track for the conveyance of passengers was laid down at the British Empire Exhibition last year and excited much interest. The track had a gauge of 24 inches, and rails of 16 lb. per yard, the total length of the circuit with a loop at each end being 2 600 yards. There was a minimum of level, the ruling gradient being 1 in. 20 and the curves varied from 60 to 80 feet radius.

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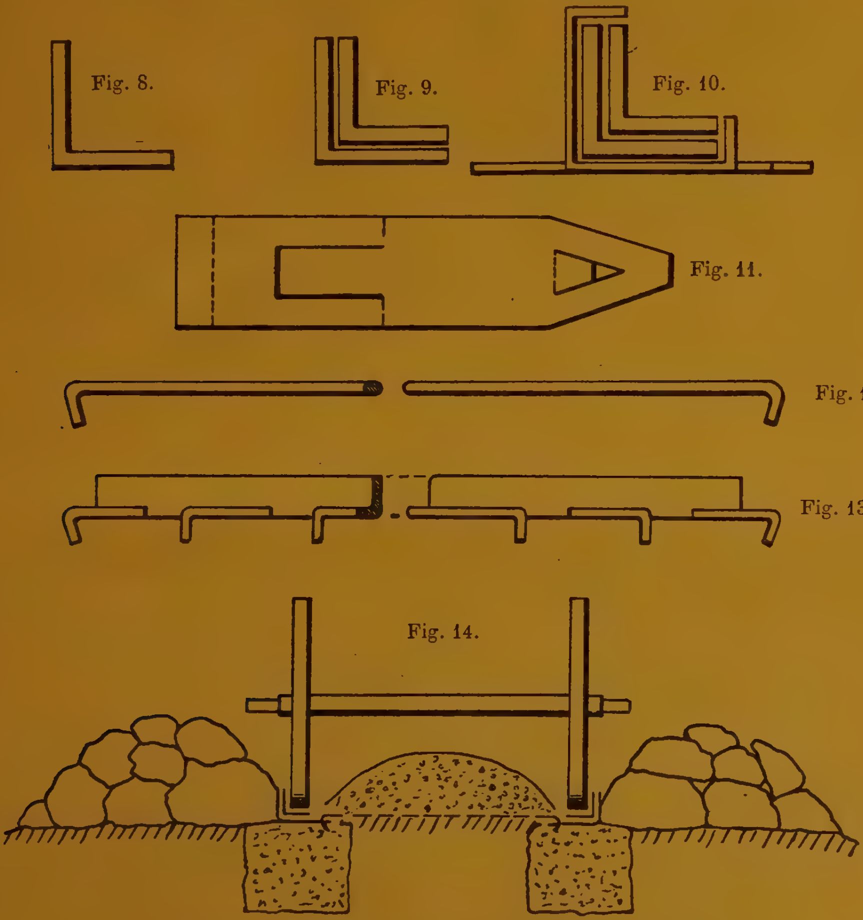
Another form of cheap transit which has been brought to notice is that of « Rutways », as illustrated in figures 8 to 14. The wheels run without any flanges on flat metal surfaces at the bottom of two deep ruts in the lowest part of the Permanent Way, and are confined to these ruts by the vertical sides of the rail angles, and by the stone ballast heaped up along either side of each rail.

The inventor of this system (Mr. W. H. Perry) states that in ordinary ground, such as the plains of India, this Rutway track can be laid down, if of 20 miles or more in length, for about £1 000, or Rs. 15 000 per mile, complete with rolling stock.

The specification of this « Underailable railway track » or « Rutway » consists of a railway track in which each rail is formed of ordinary angle iron bars laid singly or doubly as shown in figures 8 and 9 held together at intervals by means of stiff steel grips, shown in section round the angle rail in figure 10 and flattened out or developed in figure 11. These grips, and the angle bars inside them are tied to the requisite gauge by means of ordinary tie-rods, shown in figure 12. On sharp curves with heavy traffic every 4th or 5th tie-rod may be replaced by a racked angle-iron tie-bar with rack teeth biting downwards into the ground underneath, as shown in figure 13. A section of the complete track is shown in figure 14. This angle rail track is laid on and along the bottom of two deep ruts in the ballast, or, for heavy and permanent lines, on a deep concrete bedding of suitable cross-section. Ordinary flangeless wheels can travel on



Figs. 8 to 14. — Details of Rutway track.

this Rutway track, and as they are very heavy and run along the bottom of the ruts, they cannot be derailed.

* * *

I have endeavoured within the prescribed limits of this Report to show the need for a modified form of light railway construction as compared with that which has hitherto been considered necessary in some countries, if the opening out of new districts is to be encouraged and stimulus given to agriculture in all its forms by affording cheaper means of transport.

In particular, so far as Great Britain is concerned, it appears most desirable that the labours of the Light Railways (Investigation) Committee should not be overlooked and that the recommendations set out in their Report of 26 July 1921, should be given a fair trial. I desire to acknowledge the great assistance from that valuable Report in the preparation of this paper.

Some of the new methods to which allusion has been made for affording less expensive means of communication might also be examined with the view to experimental lines being constructed in undeveloped areas and the results reviewed at the Madrid meeting. If the discussions at this Congress lead to a greater interest being taken in this important subject a very useful purpose will have been served.

APPENDIX.

Detailed list of questions relating to question XIII.

LIST OF QUESTIONS.

1. — Brief history as to promotion of existing or proposed railways, including description of the districts served or proposed to be served, stating (inter alia) whether residential, industrial or agricultural, giving names of existing railways.

2. — The principal commodities conveyed or likely to be conveyed.

3. — Are railways of temporary nature, constructed in the first place with a view to permanent railways being provided when traffic warrants it ?

4. — Description of chief features of construction of railways stating :

a) Mileage, showing separately single and double tracks and sidings as distinct from branch lines;

b) Junctions with main lines, if any;

c) Exchange points or tranship points showing to what railways;

d) Gauge of line;

e) Gradients;

f) Radii of curves;

g) Types of sleepers;

h) Types of rails;

j) Method of fixing rails;

k) Nature of ballast;

l) Maximum axle-load of rolling stock used and permitted.

5. System of locomotion.

6. Speed of trains :

a) As booked;

b) Maximum authorised;

c) Maximum which, with safety, is possible.

7. — Dates railways authorised and opened for traffic, giving particulars of acts or other authority.

8. — Describe the principal difficulties encountered in the construction of railways owing to nature of strata, and the point of view of supply of materials and labour.

9. — Give topographical features of the country, including information as to necessity for viaducts and bridges.

10. — To what extent are level crossings permitted and are they protected by gates or other means, and to what extent are railways at other points protected by fencing or hedges ?

11. — Dimensions of loading gauge.

12. — Number of stations and halts.

13. — Particulars of any intermediate sidings controlled by stations.

14. — Description of accommodation provided at stations and halts :

a) Buildings;
b) Cranes and weighbridges;
c) Cattle pens;
d) Dimensions of platforms;
e) Yard, roadway and loading dock accommodation for merchandise, cattle, etc.;
f) Facilities for transhipment including particulars of transfer banks and appliances

15. — Details of methods of transhipment, including :

a) Narrow gauge trucks to standard gauge trucks, and *vice-versa;*
b) Contents of narrow gauge trucks to standard gauge trucks and *vice-versa;*
c) Any special arrangements for transhipment of coal or other heavy commodities;
d) Transhipment of water-borne traffic from boat to rail or *vice-versa;*

16. — Particulars of rolling stock showing whether owned or hired.

17. — Number and types of locomotives, showing number in steam daily.

18. — Water supply, showing source, how obtained and stored and whether pumping is involved.

19. — Particulars as to composition of trains showing :

a) Passenger trains : maximum;
— — average;
b) Freight trains maximum;
— — average;
c) Mixed trains : maximum;
— — average.

20. — Maximum gross load hauled by locomotives.

21. — Types of buffers and draw gear.

22. — Method of lighting.

23. — Method of heating, if any.

24. — Particulars of property owned by Railway Company other than that required in connection with the working of the line.

25. — Description of operation, *i. e.*, system of working (*e. g.* one engine only in steam, train staff, and ticket, electric train staff, etc.) with special reference to the absence of restrictions which are normally in force on trunk lines. Particulars of any special requirements or restrictions under acts or orders, etc., with statements as to how far such requirements are considered reasonable.

26. — Particulars of telegraphic or telephonic communications.

27. — Engine mileage for year 1922.

28. — Working time tables and appendices thereto. (Copies may be furnished and appended.)

29. — Particulars of any instances where railways are crossed on the level by other railways and description of protective measures provided.

30. — Particulars of running powers (if any) possessed by railways.

31. — Volume and earnings of traffic, showing separately passenger and merchandise, for year 1922.

32. — Particulars of organisation and staff.

33. — State form of accounts, and, if available, include copy of accounts for year 1922.

34. — Particulars of capital, showing amount authorised and amount issued.

35. — Total cost of construction of the line, including the cost of land and incidental expenses, but exclusive of rolling stock and of maintenance and repairing works and plant.

36. — Total cost of rolling stock owned by the Company, if any.

37. — Total cost of manufacturing and repairing works and plant, if any, including land.

38. — Cost of any other capital assets.

39. — Debit or credit balance of capital account at end of 1922.

40. — Gross receipts of railways for year 1922, and expenditure.

41. — Basis of fares, rates and charges, and the relation of these fares, etc., to those on the main railway systems. Indicate whether fares are charged at uniform rate or on a zone system or *pro rata* according to distance, and whether « through » fares and rates are in force. If « through » rates are in force, state how they are composed and divided.

42. — Are railways operated by owners, State or other railway companies ?

43. — If worked independently does railway company receive any allowances by way of rebates or other payments from other companies with whom traffic is exchanged. If so, give particulars.

44. — If railway worked as an independent concern, or by another company which charges the actual cost of working, details of the expenditure under the following heads should be given :

a) maintenance and renewal of way and works;

b) maintenance and renewal of rolling stock;

c) operating expenses;

d) general and other charges.

45. Information as to tonnage of traffic per train and per truck, and earnings per train, per train mile and per ton mile.

46. — Particulars of working expenses as compared with revenue, indicating any special reason for profit or loss in working.

47. — Nature and effect of road competition, if any.

48. — Average return on capital invested.

49. — Is it the practice for contractors constructing railways to accept shares in part payment ?

[625. 61]

REPORT No. 2

(all countries, except America, Great Britain and colonies,
China and Japan)

ON THE QUESTION OF ESTABLISHMENT OF LIGHT RAILWAYS (SUBJECT XIII FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

By Mr. BONNEAU,
CHIEF ENGINEER OF ROADS AND BRIDGES,
LATE GENERAL INSPECTOR OF PUBLIC WORKS IN INDU-CHINA.

In the list of questions sent out to a somewhat large number of railway companies, we had in view the comparison between the various methods adopted in the establishment of light railways for the opening up of new countries. We received very interesting replies, but many of the administrations or affiliated companies pointed out that they did not run light railways, and consequently this class of railway could not belong to the section with which we are dealing.

The material we had gathered therefore is less important than we expected, and in one of the future sessions of the Congress, it may be found worth while to reserve a special title for railways laid down to open up new countries without classifying them with those usually called « light railways ».

Generally speaking, the replies received show that the lines in question were arranged from the start with characteristics that were intended to last indefinitely and were very little altered after they were laid down.

There were certainly a few cases in which curves were reduced or some improvement added to some part or other, but we have been unable to discover any changes which could be compared with those brought about on certain transcontinental lines of North America, or to that which is at present taking place with the principal line in Corea.

All the lines from which we have received particulars are built to the metre gauge, with the exception of three connected with the Dutch Indian railways, the gauge of which is 1 m. 067 (3 ft. 6 in.). It is possible, however, that this is measured between rail centres, in which case it would be equivalent to the metre gauge between rails which is generally adopted.

We had hoped to receive some particulars relative to the lines operating in the Sahara, the most important of which is built to the standard wide gauge. The administrations, however, replied to our questionnaire that these lines could not be classed under the heading of light railways, which is quite correct.

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(1) This question runs as follows : « Methods of establishing light railways or lines for developing new countries (laying out, gradients, standard gauge, narrow gauge, etc.) »

The weight of rails varies from 20 to 26 kgr. (40.3 to 52.4 lb. per yard), but those less than 25 kgr. (50.3 lb.) have gradually been replaced by rails of heavier section, either 25 kgr. (Djibouti to Addis-Abeba line); or 25 kgr. 75 (51.90 lb. per yard) (Dutch Indies lines); or else 26 kgr. 1 (52.61 lb.) (standard type of the West African French railways).

It is rather curious to note that the sleepers used on the railways of the French colonies are almost without exception metal, whilst those of other colonies in similar districts are of wood. It seems certain, however, that when the road is laid down, if the country through which the line runs is poor in timber, or there is any difficulty in obtaining timber from the forests, it is better to make sure of a supply that can always be easily replenished by the use of metal sleepers. What happens later on in service is a matter which can be discussed later.

The rolling stock is generally composed of light locomotives of various kinds and goods wagons of 10 t. capacity. One of the lines, however, connected with the Java railways is worked with *Mallet* compounds of 60 t. similar to those used on the main line. One of the same kind of locomotives is also running on the line from Kayes to the Niger, but cannot be worked at its full capacity on account of the lightness of the rails.

Paris, 4 July 1924.

SUPPLEMENT.

Detailed questionnaire relating to question XIII.

LIST OF QUESTIONS.

1. — Name the districts served by the railways, with details of their population, principal exports and imports, and the distances from the roads of communication which existed previously.

2. — Were the lines constructed in view of being permanent, or were they constructed cheaply with the possible intention of improving the later ?

3. — Give the chief particulars as regards construction : width of road, maximum gradients both ways, radii of the curves, maximum load allowed on the bridges, etc., kind of ballast, distance between sleepers, and what the latter are made of, type and weight of rails, method of jointing, length of loop lines, standard type of rolling stock and composition of the ordinary trains.

4. — Length of time taken from commencing the work until the lines or sections of lines were opened to traffic.

5. — Give the chief obstacles met with during construction due to the form and nature of the land crossed, water courses in the way and the difficulty in the provision

of the necessary materials and water, finding of labour and supplying food, as well as sanitary arrangements.

6. — Give an account of the general costs, keeping separate as fas as possible :

preliminary work and getting out the plans; laying the road bed, bridges, etc.;

construction of the line with its accessories, such as : stations, water supply, locomotive sheds, workshops, telegraph and telephonic communication, etc., and the requisite rolling stock.

7. — State as far as possible financial expenditure : costs relating to the forming of companies, bonuses allowed to various funds or to subscribers to shares, interest, etc.

8. — Give a list of the principal additions made since opening the lines.

9. — Give particulars concerning the upkeep of the line and the special difficulties arising from the nature of the ground and water, the effect of quick sands, if any, the replacement of sleepers, and the organisation and feeding those in charge of keeping the lines in repair.

10. — State the general working conditions, such as : the relative importance of passenger and goods traffic, principal points at which traffic originates and where sent to, giving their chief traffic and mileage, the size of the trains, their total tonnage and their useful tonnage, also the distance carried: passengers, tons, trains.

11. — Give a general idea as regards rating, such as : ordinary rates and special rates most generally used both ways, also the average earning of the passenger-kilometre, ton-kilometre and train-kilometre.

12. — What are the chief working results : passenger and goods receipts ?

13. — Give the chief causes of profit and loss in working.

14. — What is the profit on capital charges and who is charged with the deficit if this takes place ?

15. — What extensions are being made or are in view, and what are the results that may be expected from them ?